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BEGINNERS

RTTY HANDBOOK

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HAVE FUN

Ever since we have been publishing the RTTY JOURNAL (almost ten years) we have felt the need for a handbook for the beginner. A reference that would explain the basic theory of RTTY operation and explain just what is needed and how to do it.

We hope this handbook will accomplish this. In addition to the basic operation we have included several rather simple but efficient pieces of equipment to achieve that end. Most of the articles are reprints from the RTTY JOURNAL or have appeared elsewhere but have been edited and in many cases brought up to date.

NO attempt has been made to make this a complete RTTY handbook. A number of other good handbooks are available but in most cases fail to take the newcomer by the hand and lead him into enjoying one of the most fascinating modes of Amateur Radio. If this book can do this we are happy.

Author's credit is given under each article but we particularly want to thank Ron Guentzler, W8BBB, associate editor of the RTTY JOURNAL for the excellent and complete article on - "RTTY FOR THE BEGINNER". Without Ron's help there would have been no handbook.

Have Fun!

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BEGINNERS RTTY HANDBOOK

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RTTY FOR THE BEGINNER --

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RTTY FOR THE BEGINNER

The purpose of this handbook is to acquaint someone new to RTTY (Radio TeleType) with the fundamentals of teleprinter operation and the application of teleprinters to transmission and reception by means of radio.

The material is divided into four general categories:
1) Teleprinters, 2) Receiving, 3) Transmitting, and 4) "Advanced" General Topics.

The approach is to begin with the assumption that the reader has zero knowledge about teleprinters and slowly build to the point where it is possible to connect a teleprinter to "talk to itself"; probably the most difficult step for a beginner is getting a teleprinter operating on a local loop (actually, it is quite easy to do, but, conceptually, it is a big step). The biggest mistake made by a beginner is to try to do too much at once without an understanding of the individual components and their functions.

Once the machine is properly operating in a local loop - "talking to itself", as it were - it is then permissible to move to receiving signals "off the air"; this is a relatively easy step. The final step is transmitting; this last step can be either very easy or quite difficult depending upon the mode of transmission desired - FSK or AFSK - and the specific method of implementing it.

Whenever possible, the "why" is explained before the "how". Understanding why something is done a particular way always helps one to understand how to do it (and how to do it better). Sometimes things are done in what appears to be a completely illogical manner (such as having loop current flowing when "nothing" is being transmitted); such "illogical" procedures generally have an historical (seemingly hysterical?) reason - once the historical perspective is gained, the "illogical" becomes superbly logical.

Most of the material in this handbook has appeared once or twice in the RTTY Journal. A series for the beginner was run in 10 installments in 1968 and 1969. It was repeated, in expanded form, as a 15 part series in 1973 and 1974. Because there is a constant influx of newcomers into RTTY, such a series rapidly loses its value because back issues become hard to obtain. Therefore, it was decided to reprint the series in a once-again-expanded form (now 18 parts), with some editing, but all under one cover. The original form of relatively small installments was considered desirable, so that form is preserved here.

THE TELEGRAPH

It will be an aid to understanding why present-day Teletype equipment works the way it does if some pertinent historical facts are discussed.

The telegraph was invented and in widespread use before the Teletype. The biggest problems with the telegraph are/were the relatively-slow speed of operation and the necessity for highly-trained operators at each end. The Teletype was invented for the purposes of increasing the speed of operation and using operators with less skill. Because the telegraph was in widespread use when the Teletype came along, much of the then-existing terminology and circuit features were incorporated into the Teletype. In fact, the term "Teletype" is a relatively-new term and is copyrighted. The most commonly-used term for Teletype was "printing telegraph", and it is still common to refer to Teletype equipment and circuits as "telegraph" equipment and circuits. The circuits used for wire-line telegraph and Teletype differ only in the equipment used at the ends.

If we examine a simple telegraph circuit and the "code" used with a hand-keyed telegraph circuit, certain similarities and some gross differences between hand-keyed - and printing-telegraphy will become apparent.

A SIMPLE TELEGRAPH CIRCUIT

Figure 1 shows a simple hand-keyed telegraph circuit. Whenever the key at the sending end is depressed, current flows over the loop or line, thru the sounder, and back to the sending end thru the Earth. The sounder is a simple device having the appearance of a relay without contacts. Whenever current flows in the sounder magnets, the armature on the sounder is attracted by the magnets, and as the armature strikes the stop it makes a click or a "sound".

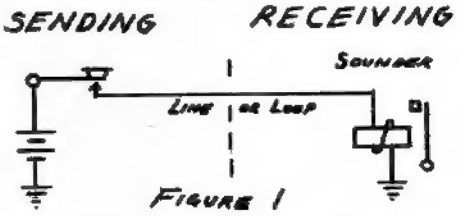


FIGURE 1

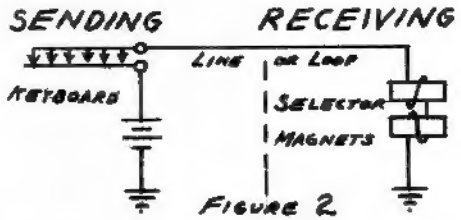


FIGURE 2

(The code used on wire-line telegraphy, the Morse code, and the code used by radio amateurs for CW operation are not the same code, although they are similar. The wire-line Morse Code used clicks of the receiving sounder while the radio code uses bursts of tone.)

One of the objections to telegraphy as just described is the neccessity for an operator to be present at the receiving end to listen to the sounder and write down what was sent as it was being sent. One solution to this problem was to have some type of device at the receiving end to make marks on a moving strip of paper in order to automatically receive a message when no receiving operator was present. The "automatic recorder" consisted of a simple arrangement containing a pen fastened to the armature of a modified sounder. Whenever the key at the sending end was depressed, the armature on the "modified" sounder would move placing the pen in contact with the moving paper and a mark was made upon the paper. When the sending key was opened, no current flowed, the armature on the "sounder" was released, and the pen was withdrawn from the paper thus making a "no mark" or a space. Because of this mode of operation the term "mark" has been used to mean the presence of current in a telegraph circuit be it hand-keyed or Teletype. No current in the circuit was, of course, called a "space". (Incidentally, the recorded message consisted of a series of "dots" and "dashes" on the paper, and someone who knew the code was required to read the message.)

(The actual order was the reverse of that given here. The original telegraph used the "automatic recorder" which gave a series of marks and spaces on the strip of paper. Someone who knew the code had to read the "recorded" message. As time went on, those who read the message from the paper strip found that they could "read" the message as it was received by listening to the clicks of the "recorder" - hence, the recorder was dropped for most uses and a simple sounder was substituted.)

Before continuing with a description of hand-keyed telegraph circuits, it will be shown how a Teletype machine fits into the scheme of things.

THE TELEPRINTER

A discussion of a teleprinter requires a separate, detailed description for each model. However, such a description would, at this point, only serve to confuse the issue. Therefore, we will take an almost oversimplified approach in order to discuss what the device does without burdening the reader with the "how" details. Some poking and peering into the innards of a teleprinter should answer a lot of questions once the "what is it supposed to do?" is answered.

There is a great similarity in outward appearance between a teleprinter and a typewriter. There are some things in common between these two devices, but the similarity soon ends when the innards are examined. In a typewriter, there is a more-or-less direct connection between each key on the keyboard and the type bar in the typebasket. When a key is depressed, the corresponding type bar is actuated.

An inspection of a teleprinter will reveal that for all practical purposes, a teleprinter is two separate machines having in common only the motor, the base, and the cover. One of the "machines", called the "keyboard" or the "keyboard-base", is composed of the keys and some device for translating the characters on each key into an electrical signal. The translation is done, commonly, by means of a mechanical arrangement that "tells" the distributor which key has been depressed. The distributor is, in effect, nothing more than a set of contacts operated by a motor. The contacts open and close at a fixed rate dependent upon the "speed" of operation (which is determined by the motor speed), and in a pattern depending upon the character or letter being sent. The distributor simply replaces the telegraph

key in the circuit shown in Figure 1, as shown in Figure 2.

The keyboard essentially replaces the telegraph key, but in addition, the "code" to be used is "stored" in the keyboard rather than in the operator's head. For example, when a manual-telegraph operator wants to send the letter "R", he must translate "R" into a code combination of dots, dashes, and spaces and then operate the telegraph key in that code sequence. When using a teleprinter, the operator only has to know where the "R" key is located. He then depresses the "R" key and the teleprinter takes over from there; it translates "R" into the code corresponding to that letter and opens and closes the contacts corresponding to that code. (Incidentally, lest the reader be misled, the code used for hand-keyed telegraphy and the code used for Teletype are not the same. This will be discussed later.)

The "other machine" under the cover is a decoding and printing mechanism. It is driven by a motor and operated by means of an electrical signal applied to the windings of a magnet. This magnet simply replaces the sounder in a manual circuit. The magnet operates, mechanically, a device known as a selector that translates or "decodes" the incoming signal and determines what letter or character is to be printed. Therefore, in effect, the printer receives the code, decodes it, and prints the corresponding character automatically, whereas with a manual system an operator is required to receive, decode (mentally), and write the character.

Again, it should be stressed that a teleprinter is essentially two independent devices. In fact, it is possible to "split" the machine and send something from the keyboard while receiving something else on the printer. (Of course, it is also possible to have the two portions connected and have the printer print something other than what is being "typed" on the keyboard; this is known as "trouble"!)

Thus far we have a great similarity between manual and "printing" telegraphy. There is one major difference however: The code that is used.

THE CODE

Perhaps a little insight into why the teleprinter code is the way it is, or at least why it is not the same code that is used for manual telegraphy can be obtained as follows.

Figure 3 (a) shows two manual telegraph characters and Figure 3 (b) shows what they would look like when viewed on an oscilloscope.

In Figure 3 (a) the letters "E" and "Q" are shown. They appear as a combination of "marks" and "spaces" between the marks. In Figure 3 (b), the corresponding pattern as viewed on an oscilloscope is shown where current flowing corresponds to a "mark" and no current flowing corresponds to a "space".

The code used for hand-keyed telegraphy is a rather ingenious combination of short and long "marks" and "spaces". The long marks are called dashes and the short marks, dots. Short spaces are used between the marks within a single character, medium-length spaces are used between characters (letters), and long spaces between words. Also, the code is set up in such a way that the more-frequently-used letters are composed of relatively-short combinations of marks and spaces (the letter E is just one short mark) while the infrequently-used characters are composed of many long and short marks and short spaces (the letter Q is composed of one long mark, one short space, one long mark, one short space, one short mark, one short space, and one long mark; no wonder it was so hard to get that CW speed up!).

This code used for hand-keyed telegraphy is suitable for operation by a person when sending to a person, but if it were to be used between two machines a major problem would develop. As mentioned, the hand-keyed characters are composed of many different-length combinations of marks and spaces and the overall character length (the time to send a complete letter) varies greatly from letter to letter; for example, the letter "Q" requires 13 times as long to send as does the letter "E". This variable-character length is a desired (or at least a not undesirable) situation when people are doing the operating, but think of the problem in devising a machine to do this! Actually, the sending "machine" would be relatively easy to construct, but the receiving "machine" would be something else. Why? Mechanical devices inherently are easiest to construct and work best when a constant, fixed length of time is required for the machine to do something. Feeding a mechanical thing a source of information that may vary over a 13:1 range (actually more if the digit O is considered) and then expecting it to digest that and always give a single response (operating one type bar) is a bit much! Therefore, the answer was/is a completely different type of code that always uses the same length of time to send a character regardless of the particular character being sent.

A code that always uses the same length of time to send a character regardless of the character is the Murray code (the code used by teleprinters). It consists of five even-length marks and spaces, and always five even-length marks and spaces regardless of the character. Because every character is always composed of five marks and/or spaces of even length it is "naturally" suited to operation from/to a mechanical device. Because there are five portions to the signal, there are only 32 characters possible. (2X2X2X2X2 equal 32). This explains why a teleprinter has only 32 keys and why the arrangement of keys has to be somewhat different from that of a typewriter.

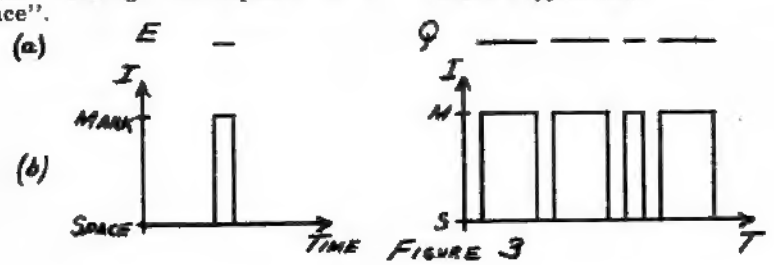


FIGURE 3

PART 2 - THE MURRAY CODE

Before commencing with the Murray code, let's review what was discussed in Part 1. In the case of manual telegraphy, the person who is sending translates the letters to be sent into a code which he sends by opening and closing a circuit with a telegraph key. The person receiving receives the message by listening to the sounder which makes a click every time the circuit is opened and closed by the telegraph key at the sending end. The "receiver" (the person receiving) translates the series of clicks into letters and writes them down. The basic objections to this system are the slow speed and the requirement for a skilled operator to be present at each end of the circuit.

In the case of printing telegraphy (Teletype), the person sending depresses a key on the keyboard corresponding to the letter to be sent; this letter is mechanically translated into the opening and closing of contacts. These contacts replace the telegraph key: At the receiving end, a magnet operates and releases an armature in response to the contacts at the sending end, and the armature, in turn, operates a selector which translates the opens and closures into the letter that was being sent.

The discussion ended with the concept that a different code than the one used with manual telegraphy was needed for use with teleprinters because a teleprinter, being a mechanical device, requires a code of uniform length regardless of the character being sent.

THE MURRAY CODE

All printing telegraphy, until recently, used the five element Murray code. Although commonly called the Baudot code, the code actually used by amateurs (by law) is the CCITT International Telegraph Alphabet #2 which is the Murray Code. For further details see: RTTY Journal, 1974 NOV, pp. 12-13, or PRINCIPLES OF TELEGRAPHY (Teletypewriter), NAVSHIPS 0967-255-0010,, S.D. Catalog No. D219.8:T23. (Amateurs are still required to use it by law, but commercially it is rapidly becoming extinct.) The code is given in Table 1. Each row lists a separate character (or pair of characters) and each column corresponds to a "time-slot" or a "bit". The M in a particular location indicates that a mark is sent at that time and an S indicates a space.

In most cases, there are two characters corresponding to each row. This is necessary because there are only 32 code combinations available in a five-element code. However, there are more than 32 chracters that one would like to send. Therefore, most of the code combinations have to be used for two things. (What the two characters are may vary greatly from machine to machine. This will be discussed later.) As an example, the first row lists "A" and "-". Which is meant when the combination MMSSS is sent?

The answer is relatively simple. Why on a typewriter do some of the keys have just one character and some have more than one? For example, the "7" key also has "&". The answer, when considering a typewriter, is to keep the number of keys to a minimum. The answer, when considering a teleprinter, is that only 32 keys are permitted. The next question is:

How do you tell a typewriter whether it is to print a "7" or an "&"? By shifting. There is a subtle point here. On a typewriter there are two kinds of shifts: 1) Locking, and 2) Non-Locking. On a teleprinter there is only one type: Locking. The shifting is done by hitting the FIGS or LTRS keys. When the LTRS key is depressed, the receiving machine performs a "stunt" rather than typing something: this stunt locks the printer in the necessary position to print the letters and characters appearing on the lower portions of the keys or the letters and characters appearing on the left side of the left column in Table 1.

When the FIGS key is depressed, the code sent from the keyboard is translated by the receiving machine to shift and lock into the position that will type what is on the upper portion of the keytops or what is shown in the right side of the left column in Table 1. Once the receiving printer is in FIGS it will remain there forever or until a LTRS is received. (Some printers are equipped with a "down-shift on space" arrangement whereby they shift to LTRS when LTRS or a character space is received. This is done for certain practical reasons that will be described later).

THE ALPHABET

The FCC states in paragraph 97, 69 (a) of the Rules and Regulations: "A signal channel five-unit (start-stop) teleprinter code shall be used which shall correspond to the International Telegraphic Alphabet No. 2 with respect to all letters and numerals (including the slant sign or fraction bar) but special signals may be employed for remote control of receiving printers, or for other purposes, in "figures" positions not utilized for numerals. In general, this code shall conform as nearly as possible to the teleprinter code or codes in common commercial usage in the United States." Table 1 gives the CCIT Alphabet No. 2 referred to above.

The arrangement of most of the characters other than the letters and numerals varies greatly from machine to machine. The reason is that different users have different requirements. Ten of the "standard" codes can be found on p. 845 of REFERENCE DATA FOR RADIO ENGINEERS, 4th Ed., IT&T. 1956.

THE CODE ELEMENTS

Let's examine the meaning of the M's and S's in Table 1. Take, for example, the row in Table 1 corresponding to the letter "Y". Going across the row from left to right, the letters MSMSM appear. This means that when the "Y" key on a keyboard is depressed, the keyboard sends a mark, a space, a mark, a space, and a mark in that order. It sends them by closing, opening, closing, opening, and closing the keyboard contacts. If an oscilloscope were placed in series with the contacts, a pattern as shown in Figure 1 would appear.

Now look at the "A" row. The letters MMSSS appear. This means that the letter "A" is sent by sending a mark, a mark, a space, a space, and a space. The pattern appearing on an oscilloscope would be as shown in Figure 2. This may appear simple enough, but a little reflection may reveal two problems: 1) How does the receiving machine know when the first mark ends and the second begins, and 2) When does the first mark begin?

TABLE 1
INTERNATIONAL TELEGRAPHIC ALPHABET NO. 2

CHARACTER	TIME SLOTS				
	1	2	3	4	5
A -	M	M	S	S	S
B ?	M	S	S	M	M
C :	S	M	M	M	S
D Who RU	M	S	S	M	S
E 3	M	S	S	S	S
F	M	S	M	M	S
G	S	M	S	M	M
H	S	S	M	S	M
I 8	S	M	M	S	S
J Bell	M	M	S	M	S
K (	M	M	M	M	S
L)	S	M	S	S	M
M .	S	S	M	M	M
N ,	S	S	M	M	S
O 9	S	S	S	M	M
P 0	S	M	M	S	M
Q 1	M	M	M	S	M
R 4	S	M	S	M	S
S '	M	S	M	S	S
T 5	S	S	S	S	M
U 7	M	M	M	S	S
V	S	M	M	M	M
W 2	M	M	S	S	M
X /	M	S	M	M	M
Y 6	M	S	M	S	M
Z	M	S	S	S	M
Line feed	S	M	S	S	S
Carriage Ret	S	S	S	M	S
LTRS	M	M	M	M	M
FIGS	M	M	S	M	M
Space	S	S	M	S	S
Blank	S	S	S	S	S

The answers to both these questions have some subtle implications.

In order to answer the first question, let's ask another question: When you copy a CW signal how do you know the difference between a dot and a dash? A dash is three times as long as a dot. You use a "mental clock" when receiving CW; you can tell whether they are dots or dashes by how long they last.

The receiving mechanism in a teleprinter also employs a "clock" or timing mechanism. The machine "knows" how long a mark is supposed to be. If a mark lasts "too long" it must be another mark!

The timing situation with printing telegraphy is more severe than it is with CW. When receiving CW you only have to be able to tell the difference between marks that differ in length by a ratio of 3 to 1. By looking at Table 1 it can be seen that the characters E, A, U, K, and LTRS contain 1, 2, 3, 4, and 5 successive marks, respectively; the receiving teleprinter must be able to "time" with enough precision to distinguish between these five characters. The receiving machine can perform this feat only by running at exactly the same speed as the keyboard on the sending machine.

The same discussion regarding successive marks can be applied to successive spaces. Again, the answer is that the receiving machine must run at the same speed as the transmitting machine in order to accurately time the signal and thus correctly decode it.

In amateur telegraphy, the length of a "time-slot" (a single mark or a single space) is 22 ms (0.022 seconds). For example, in the oscilloscope pattern in Figure 1 each mark and each space is exactly 22 ms long. In the pattern shown in Figure 2, the mark is 44 ms (2 x 22) long and the space is 66 ms (3 x 22) long.

Now to question 2. On a letter that starts with a mark, such as "A", what comes before the mark? An obvious answer, if we consider CW, is: A space. Therefore, we could say: If a space exists before a character, the beginning of any character is indicated by the transition from a space to a mark. Right? Well, try this: What does Table 1 give as the code for "C"? SMMMS. Now, if the beginning of a character is indicated by the start of a mark, when does the letter "C" begin? The answer to this paradox is that something must be sent before every character in order to tell the receiving machine that a character is coming. Before describing how this is done, a "peculiarity" of printing telegraphy must be described. Therefore, we will wait until Part 3 for the description. We will say, however, that both a mark and a space must preceed a character.

FIGURE 1

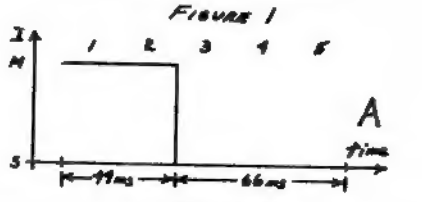


FIGURE 2

SUMMARY

The five-element Murray code was described. In order to obtain more than 32 characters it is necessary to use some code combinations for more than one character. This is done in a manner analogous to that employed on a typewriter. By shifting the machine, most of the keys are used for two separate characters. The shifting is done by means of the LTRS and FIGS keys.

Because the receiving machine must "time" the incoming signal in order to decode it, the two machines must run at exactly the same speed. Because half the characters in the Murray code start with a mark and the other half with a space, the receiving machine must be told when a character starts. In Part 3, the method for telling the receiving machine when a character starts will be described.

PART 3 - START AND STOP PULSES

In Part 2, the Murray Code was described. It was shown that it is necessary for the receiving machine to "time" the signal being received. The timing process requires that the sending and receiving machines operate at exactly the same speed. It was also shown that half the characters in the Murray code start with a mark and the other half start with a space. Therefore, some means of telling the receiving machine when a character starts must be employed.

In order to describe how this is done, a "peculiarity" of landline telegraph practice must be discussed.

TWO-WAY TELEGRAPHY

Because wire is expensive, it is desirable to use a single wire for manual telegraphy. Figure 1 shows how this is done. At each end of the circuit there is a telegraph key and a sounder in series. If a simple key that is normally open was used at each end, neither party could send because the circuit would always be open. If however, there were a switch across each key, and the switch was kept closed when not sending, the circuit could be opened by either party when he wanted to send a message and the circuit would be interrupted by his key. In this manner it is possible to have a two-way circuit with only a single wire. (Simultaneous two-way traffic could not be handled by this method, of course.)

Another advantage of the circuit being described is that other stations can be inserted into the loop (always in series) and so long as all keys are shorted while not sending, the circuit will always be continuous and any person desiring to send can "unshort" his key and send to all other stations.

Two teleprinters can be arranged for two-way operation (not simultaneous two-way) by connecting them in a manner similar to the one described. See Figure 2 and compare it with Figure 1.

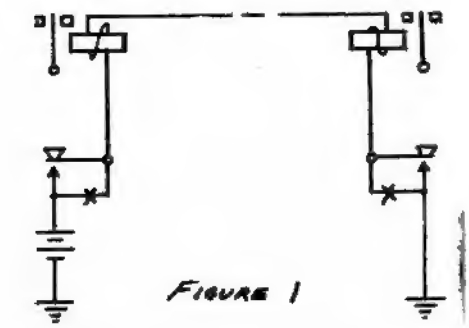


FIGURE 1

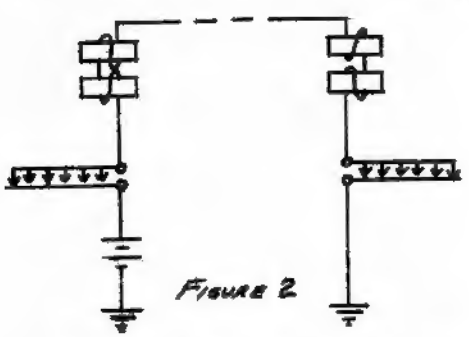


FIGURE 2

On each machine the selector magnets and the keyboard contacts are put in series. The same problem with manual telegraphy occurs here. How can one person send to the other if the circuit is opened by the keyboard contacts on the other machine? The answer is that the keyboard contacts are automatically closed when no one is "typing" on that keyboard. In other words, when the machine or the circuit is not being used, a steady mark is being sent. Therefore, teleprinters are arranged to have a steady current in the selector magnets when there is no message.

The standard schematic symbol for a teleprinter keyboard shows six contacts. One is shown closing the path. The other five are shown open. The five that are alike represent the contacts that form the five portions of the Murray code. The one that is closed is used to form the "stop pulse" to be described later and is the same contact that is closed when the keyboard is not in use.

The "peculiarity" of printing telegraphy is that something (a steady mark) is being sent when nothing (no character) is being sent.

THE START PULSE

As described above, the idle condition of a Teletype circuit is indicated by a steady mark. A steady mark is also used between characters. The receiving teleprinter, therefore, is idle when current is flowing in its selector magnets. When a character is to be sent, the keyboard contacts open the circuit, thus sending a space. The receiving printer is therefore notified that a character is coming when a space is received after a steady mark. This space is called a "start pulse". This start pulse starts the timing sequence in the receiving printer. The start pulse is the same length as the elements of the Murray code, 22 ms.

In Table 1, given in Part 2, we could have added a column before Column 1 labelled "Start", but because it would have an "S" entry in it for every row, it was not shown.

The start pulse completely resolves the paradox mentioned in Part 2. Because every character is preceded by a space (the start pulse) and that is always preceded by a mark, the beginning of every character is uniquely defined.

THE STOP PULSE

We could have also raised the question: When does a character end? This is a natural question because half the characters in the Murray code end in a mark and the other half end in a space. One answer that could be given is: 132 ms after the beginning of the start pulse. Another, and perhaps better, answer is: At the beginning of the stop pulse.

It was mentioned previously that the idle or between character condition is a steady mark. Therefore, at the end of any Murray character a mark must be sent to indicate the end of the character. In Table 1 we could have added a column after column 5, labelled it "Stop", and put an M in that column on every row; this was not done because the entry is always an M.

The stop pulse not only signals the end of a character and prepares the receiving printer to detect the beginning of another character but also acts as a buffer between characters. If the stop pulse were not used, it might be possible to send characters so rapidly that the receiving printer could not tell when one character had stopped and the next one began.

The stop pulse is unique (when compared to the start pulse and the five element pulses) in that it has a definite minimum length but an indefinite maximum length. The stop pulse starts at the end of a character and ends when the next character is sent. When is the next character sent? This depends upon the person at the keyboard.

There are two standard minimum lengths for a stop pulse. On Western Union machines it is the same as the other pulses: 22 ms. Therefore, Western Union machines are called "7.0-unit" machines because the code they send is composed of seven even-length elements. Bell System machines have a stop pulse with a minimum length of approximately 31 ms. Because 31 ms is approximately 1.42 times 22 ms, and because the other six elements are 22 ms long, the Bell System machines are called "7.42-unit" machines.

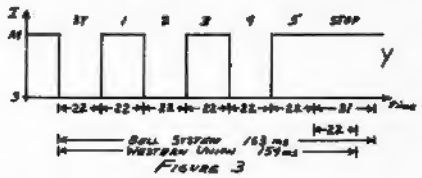


FIGURE 3

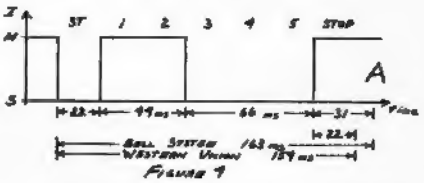


FIGURE 4

The current waveshape occurring when the letters "Y" and "A" are sent are shown in Figures 3 and 4. These are the same as shown in Figures 1 and 2 in Part 2, but contain, in addition, the start and stop pulses. The lengths of the individual elements as well as the complete character length are shown for both Western Union and Bell System machines. The mark occurring before the start pulse is the end of the stop pulse of the preceding character and may be any length greater than the minimum length corresponding to the keyboard being used. The stop pulse shown at the right of the figures ends whenever the next character is sent. Its minimum length is indicated.

We would like to mention at this point, that although Bell System and Western Union machines are 7.42 and 7.0-unit, respectively, they are perfectly compatible. The only difference is that on a Bell System keyboard the minimum interval between successive characters (the minimum length of the stop pulse) is 42% longer than it is on a Western Union keyboard.

An excellent article regarding the 7.0 vs. 7.42-unit codes can be found in the RTTY JOURNAL, 1967 March, p. 3. This article is a reprint of "Teleprinter Codes: 7 Unit Versus 7.42," F.W. Smith, Western Union Technical Review, 1954 October.

OTHER SPEEDS

For completeness, we would like to mention that amateurs may also employ 67, 75, and 100 WPM speeds. In addition, commercial stations use the 5-element Murray code described here and others use an 8-element code. "The 8-element code used in commercial service at 100 or 150 WPM operation is called ASCII.

SPEED

The term "speed" when used in connection with printing telegraphy usually means the number of words per minute that the equipment can handle. A word is defined as five characters plus a character space. Western Union characters are 7.0 units or 7.0 X 22 ms = 154 ms long. Therefore, a Western Union "word" is 6 X 154 ms = 924 ms = 0.924 seconds long. Because there are 60 seconds in a minute, a Western

Union machine can send or receive 60/0.924 ≈ 65 words per minute. Therefore, Western Union machines are called "65-Speed" machines.

Bell System keyboards have a character length of 7.42 X 22 ms = 163 ms or a word length of 6 X 163 = 0.978 seconds. 60/0.978 = 61.3 words per minute. Therefore, Bell System machines are called "60-Speed" machines.

BAUD

The Baud or the "Baud rate" is defined as the reciprocal of the shortest element length measured in seconds. For both Western Union and Bell System machines operating at 65 and 60-speed, respectively, the shortest element length is 22 ms. Therefore, the Baud rate - 1/0.022 = 45.45 Bauds.

SUMMARY

The need for the start and stop pulses were discussed. The start pulse, always a space, indicates to the receiving machine that a character is coming and starts the timing sequence in the receiving machine. The stop pulse is used to end a character and to give a steady mark in preparation for the next character. The stop pulse also acts as a buffer between successive characters to enable the receiving machine to prepare to receive the next character.

It was also shown that Western Union and Bell System machines differ in the minimum length of the stop pulse they send, but that this difference in no way affects their compatability. The speed of operation in words per minute was calculated and the Baud was defined.

PART 4 - MAKING A TELEPRINTER GO

In the first three parts, we have described some of the principles of printing telegraphy. It seems best, at this point, to show how to connect a teleprinter for obtaining local copy. By doing this, it should be possible for a beginner to "play" with this machine and to illustrate, first hand, some of the things we have discussed.

CONNECTING A MACHINE

The method used to make a printer work for local copy is simple: 1) Supply the motor whatever power its name plate asks for, and 2) Connect in series a DC power supply, a resistor, a millimeter, the keyboard, and the selector magnets. (The power supply should be capable of supplying from 110 to 300 volts when 60 mA is flowing.) Adjust the resistor until 60mA is flowing, turn on the motor, and "hit" a key on the keyboard.

Assuming all works, try proving or illustrating a few of the things we have talked about. For example: Learn where the keys are and just what the LTRS, FIGS, CAR RET, and LF keys do and how they do it. Poke, judiciously, at the machine's innards and discover what a mechanical marvel it is. Try placing a 10-ohm resistor into the loop, connect an oscilloscope across the resistor, and look at the waveforms when various characters are sent.

If any difficulties are experienced perhaps the following will help:

Before continuing, we would like to editorialize: Some "experts" state that the first thing an amateur should do when he obtains a teleprinter is rip out the wiring and, unless the motor is a synchronous motor, throw it away!! We say NONSENSE!! You may have to make some minor modifications in the wiring, but be very cautious. More on this later. As far as the motor goes, if the motor is changed, the gears will probably have to be changed also. This involves quite a bit of work. If, after you have ripped out all the wiring and replaced the motor and gears, what happens if the printer won't work? The first thing to do is determine whether it worked when you obtained it. How can you possibly know if you instantaneously ripped it apart?

THE MOTOR

Look at the name plate on the motor. If the speed is 1800 or 3600 RPM it is probably a synchronous motor. If it says it is, it is. Therefore, if it is a synchronous motor supply it the voltage it requires (probably 120 V at 60 Hz). If the printer has a lot of auxiliary apparatus with it, it would probably be best to trace the wiring and carefully isolate the two leads going to the motor, writing down just what leads were disconnected from where. You will probably want to reconnect them later so make sure that you know just what you did disconnect. Our aim at present is just to get the machine printing local copy.

If the machine has a DC governor-controlled motor, there is some auxiliary apparatus such as the governor, resistors and capacitors. Trace the wiring and determine where to apply power. If at all possible, build, even if it is only a temporary "hay wired" deal, a power supply to run the motor. (Do not use the supply for the loop to run the motor.) You will need about 110V DC at 1A. This may seem a bother, but it is better to try using the DC motor even if it is for a few minutes of operation, than it is to rip away and possibly foul things up.

For methods suitable for DC motor power see: "Some Notes on the Western Union 2B Simplex Printer", R. E. Guentzler, RTTY, 1966 March, pp. 3-4; and "Teletype-Printer Noise Reduction", R. B. Gold, QST, 1966 August, p. 71.

One further comment about motors: A synchronous motor will run at only one speed and that speed is determined by its physical construction and the frequency of the applied power. Governor-controlled motors (AC & DC) can operate over a wide range of speeds. Even when the governor is removed, the speed may vary depending upon the mechanical load placed upon the motor and the applied voltage. The nameplate on the governor-controlled motor is **not** the speed at which the motor is supposed to be operated when governor-controlled; it is the "nominal" speed when the "nominal" mechanical load and voltage is applied. For example, on some Western Union machines with governor-controlled motors the nameplate on the motor stated 1725 RPM, but the actual desired speed as controlled by the governor is 1682 RPM. On others, the motor nameplate stated 2200 RPM, but the governed speed was 2104 RPM.

THE SELECTOR MAGNETS **

There are two basic types of selectors and, of these two types, one has two possible ways to connect the magnets. These are summarized as follows:

1) Pulling magnets (60 mA, series only)
2) Holding magnets
   a) Series - 20 mA
   b) Parallel - 60 mA

What type selector does your machine have, and how should the magnets be wired? Perhaps the following will help you decide:

Older machines were equipped with a selector mechanism that was operated by the selector magnets pulling an armature which was fairly massive and required a relatively large pulling force. Consequently, selectors using this type armature are called "pulling-type" selectors and the two magnets must be wired in series and must be supplied 60 mA for proper operation.

On newer machines and newer versions of the older machines, the selector was redesigned so the armature is moved, at least indirectly, by the motor rather than by the magnets. The armature is moved up to the magnets and then released, if no current is in the magnet coils, the armature falls away. Consequently, this type selector is called a "holding-type" selector and much less magnetic force is required. Therefore, the coils can be operated in parallel and 60 mA supplied to the combination or they can be operated in series and only 20 mA is required. For various reasons, although the lower current sounds attractive, the 60 mA parallel operation is recommended.

Now comes the rub - what type selector do you have and how should you connect the magnet coils? The obvious answer is: Ask someone who knows to look at your machine and tell you what to do. Next choice is to look at someone else's machine and see how his is constructed and connected. Last choice (from an ease of doing something standpoint) is to find out all by yourself.

Trace out the wiring connected to the selector magnets. If the coils are in parallel, you probably have a holding-type selector connected for 60 mA operation. If the coils are in series, try operating the machine with 60 mA in the coils as we described at the beginning (have the motor operating and "type" something). If it operates, and it probably will, slowly decrease the loop current until operation ceases. If it stops at about 30 mA, you have a pulling-type selector and you must use 60 mA with the coils connected as they are. If operation continues down to about 10 mA loop current, you have a holding-type selector connected for 20 mA operation; reconnect the magnets so they are in parallel, adjust the loop current for 60 mA, and try operating the machine. If it works, fine; if it does not work, you have phased the coils improperly when you were reconnecting them. Reverse the leads to one magnet and try it again. It should now work.

SPEED

At what speed does your machine operate? In Parts 2 & 3 we discussed some of the "standard" operating speeds and also made a strong case for the fact that the transmitting and receiving machines must operate at the same speed. When you are operating your one machine by itself, it is operating at the "proper" speed, regardless of what that speed is, because the keyboard and selector are geared to each other and therefore regardless of the actual speed, they are operating at the correct relative speed. However, once you try to transmit to or

receive from some other machine, you must operate your machine at the proper speed relative to the other machine. Therefore, the actual speed is unimportant when making local copy, but will become vital once you "get on the air".

There are many possible ways to determine the speed of your machine. Some are much better than others; we will mention some of them and let you pick the method best suited to your situation.

1) The keyboard shaft should rotate at 368 RPM and the selector shaft at 420 RPM on a Bell System "60-Speed" machine, and the keyboard shaft should rotate at 389 RPM and the selector shaft at 420 RPM on a Western Union 65 speed machine. Obtain a Strobotac and measure the speeds.

2) If the machine has a synchronous motor, count the number of teeth on the gears (or gear and pinion) and calculate the speeds of the keyboard and selector shafts. (See Part 13.)

3) Connect your machine into a local loop with someone else's machine and send back and forth. If both machines can send and receive to/from each other, the speeds are probably correct.

4) Tune in an amateur RTTY signal and see whether you can copy it. (We have not discussed this yet, but if you are that far along, try it.) This is not the best test in the world. If you can copy, fine. If you can't there are many reasons other than improper speed that could be causing the trouble. Try several different amateur RTTY signals. Also try the reversing switch on your TU. Unfortunately, most commercial stations are not 60-speed, but if you look long enough you may find one. However, if you do find a commercial station that you can copy this may not tell you much because they operate at "standard" speeds of 60, 67, 75 and 100 WPM and which are you copying is debatable.

SUMMARY

Connecting a teleprinter for obtaining local copy is relatively simple. Supply power to the motor, and connect in series a DC power supply, the keyboard, the selector magnets, a resistor and a millimeter.

Several possible causes of trouble were discussed. It was recommended that a teleprinter be operated "as received" if possible; this is desirable because, if nothing else, it indicates whether or not the teleprinter was in operating condition when received.

A concise summary of teleprinters was given in the 1971 MAR (p. 8) and 1971 APR (p. 8) issues.

ADDENDA from original Article

**The newer machines (M32 on up), use a more complicated arrangement for operating the selector magnets. In the older machines (M28 and below), the magnets were inserted directly into the loop as already described. The inductance of the magnets presented bad transient problems that tended to distort the loop current waveform and thus cause errors in copy. The inductance problem could be mitigated by using high voltages in the loop (130 V or higher). The high voltages placed a burden upon solid state devices. Consequently, starting with the M32, the magnets have been designed to operate from about 12 V at 500 mA. They cannot be used directly in a 60 mA loop. The machine comes equipped with a solid state magnet driver (SMD) that requires 60 (or 20) mA at its input. Thus, its input is inserted into a loop in the same manner that the magnets were inserted in the older machines. The output of the SMD drives the 500 mA magnets. Therefore, there are actually three basic types of selectors.

Part 5 - TRANSMITTING A RTTY SIGNAL

It may appear a bit backward to discuss transmitting a signal before the process of receiving is considered because all amateurs receive before they can transmit (some for years!). However, if you know what you are trying to receive, it should be easier to understand why the receiving equipment is constructed and operated as it is.

TYPES OF SIGNALS

There are many ways to transmit a RTTY signal. Three simple methods are:

1. On-off keying
2. Frequency shift
   a. RF (FSK)
   b. Audio (AFSK)

The first method listed is the most obvious, especially when one is familiar with CW and the analogy between CW and RTTY that was described previously. In a simple telegraph loop, the signal is sent by opening and closing the keyboard contacts; because the keyboard contacts just open and close, it should be possible to substitute the keyboard contacts for a telegraph key on a CW transmitter and have "instant" RTTY.

This scheme will work and has been employed, but, although it represents the ultimate in simplicity for the "sender," the "receiver" may be faced with a serious problem. With this simple scheme, a mark is something and a space is nothing. What happens, when a burst of static comes along? A burst of static is something, therefore the receiving equipment mistakes the static for a mark and prints an error; the simple on-off scheme is prone to errors. (One might argue that CW is amazingly free of such problems, and on-off RTTY should be also. However, when employing CW there is one additional item that is not employed in RTTY. It is a mass of grey matter located between a pair of ears. It is capable of doing things that no electronic circuitry can come close to matching.)

FREQUENCY SHIFT KEYING

For the time being, we will ignore the differences between audio frequency shift keying (AFSK) and carrier frequency shift keying (FSK) and discuss their common features.

In a frequency shifting scheme, something is always being transmitted; i.e., the transmitter is always sending RF into the antenna. For example, whenever a mark is to be sent, the output from the sending end is a particular frequency, and, when a space is to be transmitted, a different frequency is sent. Because there is always a mark or a space being sent, the receiving equipment has a much easier time deciphering the signal.

This will be explained fully in Part 7, but a brief explanation follows:

The receiving end can copy from mark only because a knowledge of the marks implies that there are spaces between the marks. If only spaces are received, marks must be in the "gaps" between the spaces. Therefore, if both marks and spaces are sent, the receiver can use either one and obtain all the information sent. If bursts of noise are present, the receiver can employ a simple scheme where it uses both marks and spaces in such a manner to reduce its sensitivity to interference.

FSK

Carrier frequency shift keying (FSK) is most commonly employed on the HF bands. FSK is called F1 modulation).

Usually, the carrier frequency is shifted by placing a small capacitor across the oscillator tank curcuit. The capacitor is connected and disconnected by the keyboard contacts. When the capacitor is connected, the frequency of the oscillator is lowered, which results in a lower transmitted frequency (unless a heterodyne system that inverts relative frequencies is employed within the transmitter.).

Because of the unsuitability of conducting RF into the keyboard contacts, a few simple components are placed between the keyboard contacts and the frequency-shifting capacitor. These components are typically a capacitor, a diode, and RF choke, and a few resistors. The diode is used as a switch to connect and disconnect the shifting capacitor. The other capacitor and the RFC are used as a simple low-pass filter to block RF from the contacts.

Again, an FSK signal can be generated by connecting and disconnecting a small capacitor across the oscillator tank in a transmitter in response to the opening and closing of the keyboard contacts in the teleprinter.

Normally, the space frequency is lower than mark. A little reflection will reveal that if the keyboard contacts were used to add the shifting capacitor without any intervening circuitry (assuming that RF in the contacts were acceptable) the mark frequency would be lower than space. (This can happen, thus a reversing switch is usually employed in the receiving equipment to permit copying someone who is sending "upside-down".)

Typically, space is 850 Hz lower in frequency than mark. (By law it must be less than 900 Hz). Some amateurs are using a shift of 170 Hz; this is called "narrow shift". Narrow shift has many advantages compared to 850-shift, and only one disadvantage; the disadvantage is that both the transmitter and receiver must be stable (free from frequency drift problems).

AFSK

On 6 meters and above, audio frequency shift keying is permissable. (FSK is also permissable).

AFSK is usually obtained in the same general manner as FSK, but the frequency of an audio oscillator is shifted. The output from the oscillator is fed into the audio input of a transmitter.

The most common method used to obtain AFSK is to build an audio oscillator whose output frequency is as high as possible within legal limits. Usually 2975 Hz is used. A capacitor can be placed in series with the keyboard contacts and the combination is placed across the oscillator tuned circuit. When the contacts are open (space), the output of the oscillator is 2975 Hz. When the contacts are closed (mark), the resonant frequency of the circuit is lowered because of the additional capacitance and the output frequency is

lower. The most common frequency for mark is 2125 Hz (850 Hz lower than space). (Note that with FSK mark is the higher frequency whereas with AFSK mark is the lower frequency.).

The oscillator containing the shifting capacitor and usually a few other components including a diode to do the actual switching in order to keep the audio out of the keyboard contacts is called a keyer. The keyboard contacts are connected to the input of the keyer and the output of the keyer is connected to the audio input (microphone input) of an AM or FM transmitter.

When an AM transmitter is used, the modulation is called A2. When an FM transmitter is used, the modulation is called F2. When an SSB transmitter is used, the modulation is called F1 or illegal depending upon the harmonic content of the keyer and the amount of carrier suppression in the SSB transmitter. (Note that an AFSK keyer into an SSB transmitter results in an output that looks like carrier frequency shift keying so long as the keyer is well-designed and the SSB transmitter is adjusted properly.

For specific circuits of AFSK keyers see: 1. THE NEW RTTY HANDBOOK, Byron Kretzman, pp. 102-3; 2. "Audio Frequency-Shift Keying for RTTY", Irv Hoff, QST, 1965 June, p. 32ff; 3. "An AFSK Keyer", R.E. Guentzler, RTTY Journal, 1967 July-Aug. p. 9ff; 4. Part 6 of this handbook.

SUMMARY

Because RTTY is sent over a local loop by simply opening and closing contacts, we will not attempt to discuss a specific FSK circuit at this point because the actual circuit to be used depends upon how the voltage used to operate it is obtained. This will be covered in detail in Parts 10, 11, and 12.

This method, called "Indirect FSK," will be covered in Parts 10 and 11.

It is possible to substitute the keyboard contacts for a telegraph key on a CW transmitter. This means of transmission is very difficult to receive except under very favorable conditions. A better method known as frequency shift keying requires the transmitter to be on continuously whether a mark or space is being sent. The carrier frequency can be shifted between two frequencies, one for mark and a lower frequency for space (FSK or F1). On 6 meters and above a voice transmitter can be used and the frequency of an audio modulating signal can be shifted (AFSK, F2 or A2). With either FSK or AFSK the frequency can be shifted by placing a capacitor across the tuned circuit in the oscillator.

Part 6 - AN AFSK KEYER

In Part 5 we described the two principal methods used to transmit a RTTY signal: 1) Frequency shift keying (FSK), and 2) Audio Frequency Shift Keying (AFSK) It was shown that they are in some ways quite similar in that the frequency of an oscillator is shifted between two different frequencies as the contacts on the keyboard of a teleprinter open and close. In the case of frequency shift keying, the frequency of the oscillator within the transmitter is shifted. This is usually accomplished by slightly modifying the oscillator circuit within the transmitter.

In the case of audio frequency shift keying, the frequency of an audio oscillator is varied between two different frequencies as the keyboard contacts open and close. The output of the audio frequency shift keyer is connected to the microphone input of a voice transmitter (AM or FM). Because the AFSK keyer is not built into the transmitter, essentially any AFSK keyer can be used with any voice transmitter. (Of course, the input impedance of and level required by the transmitter will have some effect upon the specific requirements of the AFSK keyer, but the restriction can be considered minor.)

THE AFSK KEYER

Although an AFSK keyer can be built with a single oscillator and a capacitor placed across its tuned circuit to shift the frequency, more versatility and reduced keying transients can be obtained by using two separate continuously-running oscillators whose outputs are "gated" by the opening and closing of the keyboard. The two major advantages of separate oscillators (one for mark and one for space) are:

1) The frequency of each oscillator can be adjusted independently of the other, and
2) The levels of mark and space tones can be independently adjusted.

The circuit will be described briefly and then various portions of the circuit will be described in some detail.

The oscillators use the familiar Hartley circuit consisting of an 88 mH toroid shunted by the proper amount of capacitance to give the required 2125 and 2975 Hz resonant frequency. The values shown for C3 and C4 are the approximate values required. The exact values should be determined by measuring the output frequency and adjusting the capacitors until the frequency is proper. The capacitors can be "varied" by shunting small mica capacitors across C3 and C4.

The oscillator transistors are TI 2N3819's. These are N-channel junction field effect transistors. The resistors R1 and R2 and the capacitors C1, C2, and C5 are for decoupling. R1 and R2 can be used to measure the drain current on the transistors. It should be from 4 to 8 mA.

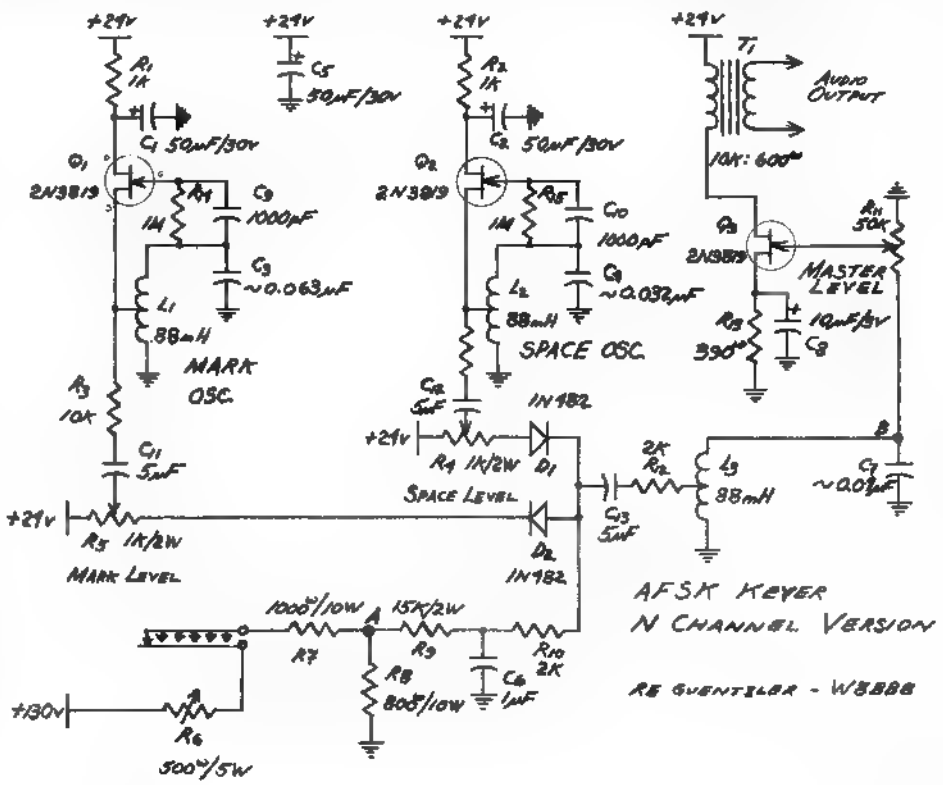
The keyboard is connected into a "loop" composed of R6, R7, and R8; the loop is fed from 130 V or higher. R6 is adjusted to give a loop current of 60mA. (Actually, R6 is not really necessary and the loop current does not have to be set to 60 mA unless a selector is also put into the loop. The selector is undesirable for reasons described later, but "force of habit" or good telegraph practice indicate that 60 mA is desirable.)

Assuming that R6 is present and it has been adjusted to give 60 mA loop current, during marking condition from the keyboard (contacts closed and 60 mA flowing in the loop) the potential at point "A" is approximately plus 48 volts; during the spacing condition (no loop current), the potential at point "A" is approximately 0 volts. This variable potential is coupled into the diodes D1 and D2 thru a delay network composed of R9, C6, and R10. The varying potential at point "A" causes one of the other of the diodes to conduct. For example, during a mark the potential at point "A" is 48 volts; this voltage causes diode D2 to conduct or gate the output from the mark oscillator into the output amplifier Q3. The output from the space oscillator will be blocked from Q3 because D1 is reverse biased.

During a space, the voltage at point "A" is approximately 0 volts causing D1 to conduct and D2 to open. Therefore, during a space the output from the space oscillator is connected to Q3 via D1 and the output from the mark oscillator is blocked from Q3 by non-conducting diode D2.

R4 and R5 control, independently, the levels from the two oscillators while R11 controls both levels simultaneously.

The network composed of R12, L3, and C7 is essentially a "simple-minded" band



pass filter. The output stage is a common-source amplifier transformer coupled to the transmitter audio input circuit.

Capacitors C1 and C2 can be any value greater than 1 uF. C5 should be as large as possible.

It was found that the frequency of the oscillators changed less than 1 Hz when the supply voltage was varied from 18 to 26 volts. With stability that good, no regulation is required.

The diodes should be silicon junction diodes. This is desirable in order to get a good forward to backward resistance ratio with the magnitudes of oscillator and switching voltages available. We used the 1N482.

The switching delay network composed of R9, C6, and R10 can be changed if more diode current is required or if the time constant is considered too long. In the circuit shown, the total switching time is approximately 8 cycles at 2125 Hz or about 4 ms. If the 1N482 is used, the network is optimum.

The "filter" network composed of R12, L3, C7, and R11 is tuned to resonate at approximately 2550 Hz. The best tuning procedure is to adjust the size of C7 so that the mark and space tones appear at the output at equal levels when R4 and R5 are wide open. The Q of the L3-C7 circuit is kept low by using the 50K potentiometer (R11) and the coupling resistor R12. This filter serves several purposes: 1) It cleans up any harmonics from the oscillators, 2)It removes the harmonics generated by the diodes during the switching interval when the diodes are partially-conducting, and 3) It helps remove the low frequency transients caused by the DC used to switch the diodes.

The 24 V power supply should be "stiff" so that the loop keying does not affect the keyer in a manner other than the desired one.

When wiring the unit, it is advisable to separate the wiring in the loop circuit from the remainder of the unit. This is desirable because "spikes" may be present in the loop due to bouncing contacts, etc., and these "spikes" could get into the output and into the transmitter.

One note of caution: As is the usual case, too many selector magnets in the loop will cause spacing bias on the transmitted signal. The spacing bias can be reduced by decreasing the size of R8. The best way to eliminate the bias is to prevent it; i.e., don't put selector magnets in the keyboard loop!

CONCLUSION

We have just described a good AFSK keyer. It is slightly different from most others described elsewhere in that it uses two separate oscillators and the output from these oscillators is gated by means of two diodes.

We have had one of these units running 24-hours/day for over 6 years now and there has been no sign of deterioration in performance. (About 50,000 hours of continuous operation!)

Part 7 - RECEIVING RTTY SIGNALS

In Part 5 we described how an RTTY signal is transmitted. This was done before describing how to receive a signal because it was felt that it is easier to understand how to receive something if one knows what that "something" is. We will review the transmitting process and then describe the receiving process.

There are two methods used to transmit an RTTY signal. Both involve frequency shifting a signal. One method employs frequency shifting the carrier from a CW transmitter. The other method involves frequency shifting an audio tone which is applied to the microphone input of a voice transmitter (FM or DSB AM). The former method is called FSK and the latter method is called AFSK. Which method is used is dependent upon legal restrictions and/or technical problems. Generally, FSK is used on 10 meters and below, and AFSK is used on 6 meters and the above.

FSK is obtained by connecting the keyboard contacts to the oscillator circuit in a CW transmitter. The connection is made thru a simple circuit consisting of a diode, an RFC, and a few resistors and capacitors. This shifting circuit is placed physically close to the oscillator in the transmitter. When the keyboard contacts are closed (Mark), the output from the transmitter is a particular desired frequency (for example, 3,600 MHz). When the contacts open (Space), the frequency of the oscillator is shifted downward by some desired amount; when "wide-shift" is being used, the frequency is shifted downward by 850 Hz during a Space. (If 3.600000 MHz were used for Mark, the space frequency would be 3,599150 MHz).

It should be emphasized that something is always being transmitted; i.e., regardless of whether a mark or space is being sent, the transmitter is "on the air" and RF is being fed into the antenna. The only difference between Mark and Space is that the output or transmitted frequency is slightly different.

AFSK is obtained by building (or buying) an audio oscillator that contains a shifting circuit similar to the one that was used in the FSK transmitter oscillator circuit. When a Mark is to be sent, the output from the audio oscillator is a given frequency (typically 2125 Hz). When a space is to be sent, the output from the audio oscillator is shifted upward in frequency. Usually, a shift of 850 Hz is used; therefore, if the Mark frequency is 2125 Hz, the Space frequency is 2975 Hz. The audio oscillator and its shifting circuit are called, collectively, an "AFSK Keyer" and this keyer is housed in a box that is physically separate from the transmitter. (That is, with FSK the shifting circuit is built into the transmitter, while with AFSK the shifter and its oscillator are located external to the transmitter.) The output from the AFSK keyer is connected to the audio input of an FM or DSB AM transmitter.

THE BASIC RECEIVING PROCESS

Whether the signal to be received is FSK or AFSK, there are certain similarities in the receiving process. In the case of AFSK there are essentially two steps and with FSK there is an additional step. We will describe the AFSK situation first.

The two steps to receiving an AFSK signal are: 1) Tune the receiver so that the AFSK tones are heard in the loudspeaker, and 2) Apply the tones coming from the receiver to a "terminal unit" (TU), or a "receiving converter", or a "decoder", whichever you prefer to call it, and connect the output of the TU to the selector magnets in the printer.

The receiver tuning process for AFSK is quite simple. Because the signal being transmitted was generated by applying audio-frequency tones to the microphone input of an FM or DSB AM transmitter, the receiver is tuned in exactly the same manner as it would be for a voice signal.

The TU and the process within it will be described briefly in order to present the basic processes taking place within it. A more detailed description will be given in Part 8.

As mentioned above, the audio output from the receiver is fed into the TU. This audio signal is composed of two tones one at 2125 Hz representing a Mark and one at 2985 Hz representing a Space. Only one tone is present at any one time. Inside the TU is a pair of tuned circuits; one circuit is tuned to the Mark audio frequency and the other to the Space audio frequency. When a Mark tone is received there is an output from the Mark tuned circuit and none (or very little) from the Space tuned circuit. When a Space tone is received, there is an output from the Space tuned circuit and none from the Mark tuned circuit. The output from these tuned circuits is an audio frequency voltage (AC). These AC voltages are rectified (converted to DC) by a circuit similar to that used in a power supply. There is one rectifier circuit connected to each tuned circuit. The diodes in one of the rectifier circuits are reversed from the way those in the other circuit are connected. Therefore, for example, when a Mark tone is received a positive DC voltage results whereas when a Space tone is received a negative voltage is produced. This DC voltage is too weak to directly operate selector magnets and is amplified. The amplification can be accomplished by means of a polar relay, a vacuum tube, or a transistor. The amplified voltage is applied to the selector magnets.

To summarize the AM or FM AFSK receiving process: The tones are received on an "ordinary-type" AM or FM voice receiver as would a voice signal. The tones coming from the receiver are fed into a terminal unit (TU). The TU separates the two tones, converts them to DC, and then turns on and off a DC loop connected to the selector magnets. The DC loop is turned on when a Mark tone is received and off when a Space tone is received.

RECEIVING FSK

The FSK receiving process involves three steps: 1) Tuning in the FSK signal, 2) Converting the FSK signal into an AFSK signal, and 3) Converting the AFSK signal into a DC loop signal by means of a TU.

The last step will be considered first because we have already discussed it. The TU used for FSK can be the same one used for AFSK so long as the tones applied to it are AFSK tones of the proper frequencies.

How do you get AFSK tones from a receiver tuned to an FSK signal? The answer is the same as the answer to the question: How do you get a tone from a receiver when receiving a hand-keyed CW signal? The answer is: Use the BFO in the receiver. When receiving a hand-keyed CW signal you are trying to listen to a single carrier or RF signal that is simply going on and off. By means of the BFO you (or, rather, the receiver) converts that single carrier frequency to an audio frequency. The pitch (or frequency) coming from the receiver is dependent upon the difference between the transmitted frequency and the frequency of

the BF oscillator within the receiver, if the carrier frequency of the received signal varies, the pitch of the tone from the receiver varies. If you tune in an FSK RTTY signal, the tone coming from the receiver will change as the transmitted signal changes frequency. Therefore, the first two steps involved in receiving an FSK signal are more-or-less accomplished simultaneously.

Now come some problems that occur with FSK that do not occur with AFSK. In order to describe and understand these FSK problems, let's look at AFSK again. When a person is transmitting voice or AFSK on an FM or DSB AM transmitter, the audio frequencies he sends are determined by him. When you tune your receiver to hear his signal, you tune for maximum signal or least noise but in the tuning process you do not change the frequencies being heard. You merely optimize what you are hearing. In the TU the tuned circuits are tuned so that one gives maximum response to Mark tone and the other to Space tone. In order to greatly simplify what could become a messy tuning problem, certain standards have been set up for AFSK RTTY and one of them is that when using "850-shift" the Mark tone is always 2125 Hz and the Space tone is always 2975 Hz. Therefore, once you have built your TU you should not have to retune it everytime you receive an AFSK signal because "everyone" uses 2125 Hz for Mark and 2975 Hz for Space.

When you tune a CW signal, you tune for a combination of things including maximum signal and least noise. When tuning you also change the pitch of the signal. This pitch is not particularly important because your head contains a rather broadly-tuned circuit that will accept almost any pitch. When you tune an SSB signal you have a slightly tougher situation than with CW because you have to tune to get the voice frequency components in approximately their proper range in order to understand what the person is saying, but there is still some room for error and your head will compensate for it. However, the tuning is more critical than it is with CW.

Now back to FSK. When you tune in an FSK signal, your tuning determines the pitch of the received tones. If his transmitter or your receiver drifts, the pitch of the received signal changes as it does with CW or SSB. However, because the TU contains rather sharply-tuned circuits, the audio tones presented to the TU must match rather closely the frequencies to which the circuits are tuned. Therefore, when you receive an FSK signal you must tune for the proper pitch of tones and a slight drift in frequency at the transmitter or receiver may alter the frequency of the received tones enough to cause errors in the printed copy or prohibit copy.

For example, if either end drifts by 100 Hz, the tones will change by 100 Hz. and this may be enough to prohibit copy. A change of 100 Hz at a frequency of 3.600 MHz is a change of one part in 36 thousand or approximately 0.003%. At ten meters a change of 100 Hz is approximately 0.0003%. This represents a pretty tight frequency tolerance.

Again, a problem with FSK reception is that the person receiving determines by his tuning what audio tones will appear from the receiver. This means that the tuning process is more difficult than with AFSK. Also, any drift in frequency at either end will directly result in an error in the tone output frequency from the receiver. With AFSK a tuning error is either totally unnoticed, or, at worst, may result in a change in noise level from the receiver.

Another problem with FSK although not as serious, is that by improper tuning you may end up with an "upside-down" signal. This is analogous to what happens when an SSB signal is tuned on the "wrong" side (trying to receive with the mode switch in "LSB" when it should be in "USB"). You might tune in the signal so that one tone is exactly 2125 Hz and the other is 2975 Hz but get nothing but "garbage" from the printer. The problem is that space is 2125 Hz and Mark 2975 Hz! (Incidentally, this could also be the fault of the transmitting station.) A simple remedy for this situation is to incorporate within the TU a "reversing" switch that permits the interchange of Mark and Space signals.

SUMMARY

We have briefly reviewed the two methods of transmitting RTTY signals. It was pointed out that when AFSK is received a voice type receiver is used and the tones being transmitted are heard in the loudspeaker. Tuning the receiver optimizes reception of the tones but does not change their pitch or frequency. The tones are fed from the receiver into a terminal unit (TU). The TU separates the tones by means of two filters or tuned circuits, converts the outputs of these filters into DC, and applys the DC to a loop keyer which operates the selector magnets in the printer. The loop keyer may be a polar relay, a vacuum tube, or a transistor.

When FSK is to be received, the receiver must receive the signal (obviously) and convert the FSK signal to audio tones or AFSK. (The conversion to AFSK is the same process used to receive CW or SSB.) Once the AFSK signal has been generated within the receiver a TU is connected to the output of the receiver as it was for a pure AFSK situation. The prime difficulty with receiving FSK is that the frequency of the tones appearing at the receiver output is dependent upon the tuning of the receiver, and precise tuning is required compared with the rather sloppy tuning required with AFSK. Also, any drift of the receiver or transmitter when using FSK will result in a shift of the frequency of the tones coming from the receiver, and even a relatively minor drift (when compared with AFSK or DSB AM voice) will result in loss of copy. TUs will be described in more detail next.

Part 8 - A SIMPLE TU

The fundamentals of the receiving process for FSK and AFSK signals was described in Part 7.

When an AFSK signal is received, the receiver (AM or FM) is tuned to the signal and the tones being sent are heard in the loudspeaker. The frequency of the tones is not affected by tuning the receiver; tuning merely optimizes for minimum noise. When an FSK signal is received, the receiver is operated as it would be for a CW signal (or more accurately, as it would be for an SSB signal). When the receiver is tuned, the FSK signal appears as tones coming from the loudspeaker. The tuning of the receiver affects the frequency or pitch of the tones as well as the relative amount of interference and noise. Therefore, the receiver must be tuned so that the FSK signal has exactly the right pitch.

In either case (AFSK or FSK), the tones coming from the receiver audio output are applied to the input of a TU. The TU has the job of distinguishing the Mark and Space tones, and, ultimately, opening a loop when a Space is received and closing a loop when a Mark is received. The loop is connected to the selector magnets in a teleprinter.

A SIMPLE TU

We are going to describe a simple TU in order to show how a TU converts the audio tones into the opening and closing of a loop. We have selected the Twin City TU for two reasons: 1) It uses vacuum tubes and will therefore be understandable to the maximum number of readers, and 2) it contains all of the absolutely necessary circuitry, but at the same time is simple enough to be easily understandable.

When looking at the circuit diagram it will be noticed that no component values are given. We did this because we are trying to remain neutral in the area of which TU is the best for a particular application. Anyone interested in building the Twin City TU can find it in: THE NEW RTTY HANDBOOK, Byron H. Kretzman, W2JTP, Cowan Publishing Co., 1962.

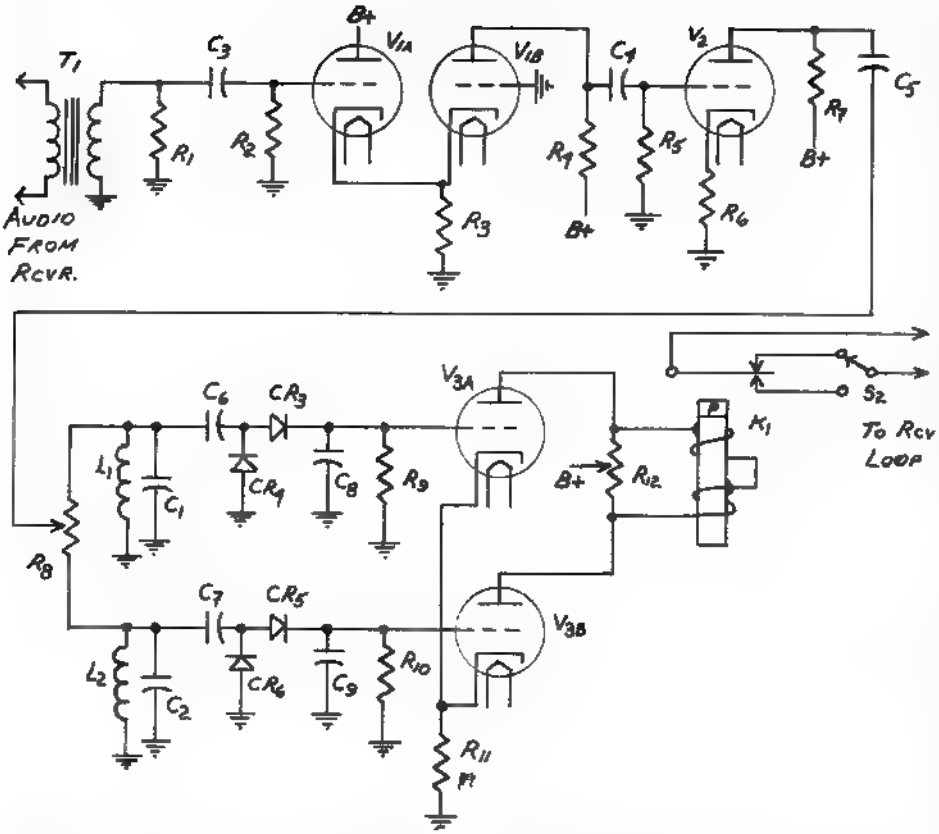
The circuit can be divided into several separate and essentially independent portions as follows: 1) input "amplifier" and isolation (T1. R1). 2) Limiter (C3, R2, V1, R3, R4) 3) Amplifier (C4, R5, R6, V2, R7), 4) Space and Mark filters (C5, R8, L1, C1, L2, C2), 5) Space voltage doubler reactifier (C6, CR3, CR4, C8), 6) Mark Voltage doubler rectifier (C7, CR5, CR6, C9), 7) DC amplifier (R9, R10, R11, V3, R12), and 8) Loop keyer (K1).

1) The input "Amplifier" and isolation is obtained by means of transformer T1. The AFSK signal obtained from the loudspeaker terminals of the receiver is relatively weak. By running it thru a transformer the signal voltage can be increased many times. Also, the input transformer provides isolation thus preventing possible introduction of noise due to "Ground loops".

2) The purpose of the limiter is to provide to the rest of the unit, especially the DC amplifiers, a signal relatively independent of the strength of the tones coming from the receiver.

3) The amplifier composed of V2 and its associated components is needed to increase the constant but relatively weak signal coming from the limiter to a magnitude large enough to insure that the DC amplifiers have adquate signal. The output from the amplifier V2 consists of the same audio tones that came from the receiver output; the processing of the signal to this point simply amplifies the tones to a constant level.

4) The signal from the amplifier is delivered to the Space and Mark filters thru R8. R8 serves the purposes of effectively isolating the filters from each other, and because it is variable, permits compensation for differences within the two filters. The Space filter composed of L1 and C1 is a simple parallel resonant circuit tuned to the Space frequency of 2975 Hz. At resonance it has a relatively high impedance, but off resonance the impedance is relatively low. If a constant-amplitude, variable-frequency signal is fed from V2 to the L1-C1 filter, the voltage across the filter will be a maximum at its resonant frequency and smaller at other fre-



quencies. For example, when a 2975 Hz tone is fed from the plate of V2, the audio voltage across L1-C1 may be about 10 V, but when a 2125 Hz voltage of the same value is fed from the plate of V2 only about 1/2 volt will appear across L1-C1. This is similar to the action of any tuned circuit. The Mark filter composed of L2-C2 acts in exactly the same manner except its voltage is maximum when a 2125 Hz tone is present and quite small when a 2975 Hz tone is present.

Before continuing, we will summarize operation up to the filter outputs. The audio signals from the receiver are amplified, then limited, then amplified again. Therefore regardless of the frequency of the tone the voltage appearing at the plate of V2 is the same. The signal from the plate of V2 is split by means of R8 and is applied simultaneously to the two tuned circuits composed of L1-C1 and L2-C2. L1-C1 is tuned to the Space frequency, 2975 Hz, and, L2-C2 is tuned to the Mark frequency, 2125 Hz. Therefore, when a Space tone is received the voltage across L1-C1 is relatively large (10 V) and the voltage across L2-C2 is relatively small (1/2 V). When a Mark tone is received, the voltage across L1-C1 is relatively small (1/2 V) and the voltage across L2-C2 is relatively large (10 V) Because of dissimilarities within the circuit, the voltages may not be exactly as stated. This can be partially compensated by adjusting R8.

5) The Space voltage doubler rectifier circuit (C6, CR 3, CR4, C8) converts the audio frequency voltage appearing across the Space filter into a positive DC voltage which is approximately proportional to the audio voltage appearing across the Space filter.

6) The Mark voltage doubler rectifier rectifies the audio voltage appearing across the Mark filter and delivers a positive DC voltage approximately proportional to the audio voltage appearing across the Mark tuned circuit.

7) One portion of the DC amplifier (V3A) amplifies the positive DC voltage appearing from the Space voltage doubler rectifier and the other half (V3B) amplifies the DC voltage from the Mark voltage doubler rectifier. The common cathode resistor R11 serves the purpose of making one of the DC amplifiers discriminate against the other one. For example, when a Space tone is received, the voltage appearing on the grid of V3A may be about 20 volts and the voltage appearing on the grid of V3B may be only 1/2 volt. (These are voltages measured to ground). Because the grid on the V3A is being driven rather hard, the plate current on V3A will increase significantly and this will increase the voltage across R11 making both cathodes more positive with respect to ground than they were with no signal. The Space tone resulted in about 1/2 V appearing from the Mark circuit on the grid of the Mark triode (V3B). However, the cathode voltage on V3B has increased thereby cancelling the effect of the small Space voltage appearing on the Mark grid. When a Mark tone is received, the Mark triode V3B receives the larger voltage and it (V3B) discriminates against V3A The net result is that the plate current in the triode receiving the signal will be about 10 mA and the plate current in the other triode will be about zero mA.

8) The combination of R12 and K1 translate the varying plate current from the two halves of V3 into loop opens and closures. K1 is a polarized (polar) relay such as the 255-A. When current flows thru the windings in one direction, the armature operates in one direction and when current flows thru the windings in the other direction the armature moves in the opposite direction. For example, when a Space tone is received, current flows from B positive thru the top half of the R12 into the plate of V3A and from B positive thru the bottom half of R12, up thru the relay windings, and into the plate of V3A. This operates the armature in one direction. When a Mark is received, the current flows from B positive down thru the bottom half of R12 and into the plate of V3B; it also flows from B positive up thru the tophalf of R12, down thru the windings of K1, and into the plate of V3A. Because the current is now flowing down thru K1, the armature moves in the opposite direction closing the opposite contact. The armature of K1 and only one contact are inserted into the local loop. Therefore, when the armature of K1 is operated in one direction the loop is closed, and when operated in the other direction the loop is open. By operating switch S1, either relaycontact can be used to close the loop. This permits interchanging Mark and Space in case the signal being received is "upside-down."

SOLID STATE TUs

An inconsistency exists between Part 7 and 8. In Part 7,we said that the diodes used to rectify the outputs from the tone filters were reversed in one of the circuits; thus a positive voltage was present when a Mark tone was received and a negative voltage was generated when a Space tone was received. In the circuit discussed, both tuned circuits fed diodes which were connected to give positive output voltages. Why the apparent discrepancy?

The answer goes something like this: It is desired to have the loop closed when a Mark is received and to have it open when a Space is received. When a polar relay is used, its direction of operation is sensitive to the direction of the current thru its windings. Therefore, if a positive voltage (or current) is applied to one end of the coil, the relay will close its contacts. If a positive voltage (or current) is applied to the other end of the relay coil, it will open its contacts. In the circuit described in this part (the Twin City TU), the positive voltage from the Mark circuit is applied (after amplification by V3A) to one end of the relay coil. The positive voltage from the Space circuit (after amplification thru V3B) is applied to the other end of the relay coil. Thus the Mark and Space signals are effectively subtracted within the polar relay. (Some subtraction occurs in the common cathode circuit of V3, but the bulk of it is done in the relay).

If an NPN transistor is used to key the output loop, it requires a positive voltage to turn it on and a negative voltage to turn it off. Therefore, the signal applied to the base of the transistor must be alternating plus and minus. This can be accomplished by simply taking the dc outputs from the Mark and Space tuned circuits and subtracting them. The subtraction can most easily be accomplished by reversing the diodes connected to one of the tuned circuits, and then simply adding the dc signals. (Adding numbers of opposite sign is the same as subtracting two numbers of the same sign.)

Because silicon transistors will turn off with no bias, the Mark signal alone could be used to operate the loop keying transistor. However, the transistor operation is better if it is purposely turned off, and, especially if noise or fading are present, it is better to use the difference between Mark and Space to operate the output loop, rather than either one alone.

A third way to develop the plus and minus voltages is by means of a phase-locked loop (PLL). The PLL "tracks" the incoming audio tones, and, while do-

ing so, it internally develops a dc voltage whose polarity is dependent upon the frequency of the tones - this is done without diodes.

The loop keyed by the TU must be either on or off - no intermediate state is permitted. With a polar relay, the contacts are either open or closed, so no problem exists. However, a transistor can exist in a partially conducting state; thus a circuit should be interposed between the diodes or the output of the PLL and the loop keying transistor to make a firm decision as to whether a Mark or Space is present so that the loop keying transistor will either be on or off. Such a "decision-making" circuit is called a comparator, Schmitt trigger, or "slicer."

Three TUs are representative of various degrees of complexity. Harry Legler, WØPB, presented the F2 TU in QST, 1973 JAN, p. 25ff. It contains only one transistor; the "diodes" (bridge rectifiers) are oppositely poled to give the subtracting action. The NS-1 PLL Demodulator, Nat Stinnette, W4AYV, RTTY J., 1974 OCT, pp. 6-7, uses a phase-locked loop followed by a comparator. The ST-5, Irv Hoff, W6FFC, RTTY J., 1973 MAY-JUN, pp. 3-12, uses oppositely-poled diodes to subtract the Mark-Space signals which are then run thru a "slicer".

Solid-state TU circuits complete with parts values are given at the end of this handbook.

SUMMARY

We have just described the operation of a simple TU and variations required when a transistor is used to key the loop in place of a polar relay. In Part 9, we will describe some additional circuitry which is desirable when receiving signals that contain QRN, QRM, and QSB.

Part 9 - DESIRABLE COMPLEXITIES

The Twin City TU was described because its basic principles of operation are similar to those of more complex units; i.e., the Twin City TU contains the fundamental or "absolutely" necessary circuits found in any TU. It is a unit that can be used with FSK or AFSK. It is a relatively simple unit that will give excellent performance on reasonably good signals, but is not the best performer when the going gets rough (QRM, QRN, QSB).

We are not going to describe the specific circuit modifications that can be made to the Twin City TU, but, instead, we are going to point out some of the reasons why a basic unit such as this may not perform well under poor conditions. The possible solutions to be described have been incorporated into many other units.

THE LIMITER

We discussed the limiter and indicated that its purpose is to present a signal of constant strength to the remainder of the unit essentially independent of the audio signal being supplied to the TU by the receiver. This is a desirable situation because at some point within the TU a decision must be made as to whether a Mark or Space is being received so that the loop being controlled by the TU can be closed or opened, respectively. The decision-making process is uniform when a signal of uniform strength is presented. The limiter not only presents a uniform-strength audio signal independent of "volume control" setting on the receiver, but it also corrects for one tone being louder than the other; this can result from many causes including the frequency response characteristics of the receiver.

So far, the limiter does nothing but good; however, what happens when a noisy signal is being received?

In order to gain some insight into the answer to this question, digress for a moment. Frequency-shift keying, be it carrier frequency shift keying (FSK) or audio frequency shift keying (AFSK) is a form of frequency modulation. The "better" FM receivers normally use two or more limiters before the detector stage. With FM receivers, when two signals are present simultaneously, the louder or stronger of the two signals "captures" the receiver and will almost totally suppress the weaker signal unless the two signals are very nearly the same strength. If a signal and noise are present simultaneously, they can both be thought of as signals and whichever is stronger will capture the other. The net result is that when working with FM signals (RTTY, voice, or music) the desired signal is either there and of good quality or not there at all. This is because when the signal is stronger than the noise, the limiters tend to suppress the noise; when the noise is stronger, the limiters tend to suppress the signal. (The so-called "noise free" characteristics of FM have led to two common fallacies: 1) FM is noise free, and 2) FM is better than AM. Actually : 1) When an FM signal is strong, it swings, and 2) When the going is rough, AM is better than FM).

Now back to the TU. So long as the noise is less than the signal, the limiters do their job of equalizing levels, and, in addition, tend to suppress noise. However, when a signal gets noisy, the limiters tend to suppress the signal in favor of the noise! The obvious solution appears to be that the limiters should be dispensed with. In general, this is not the answer. although it does, upon occasion, have benefits; i.e., "limiterless" or "AM" operation of the TT/L-2.

A large improvement can be gained by reducing the noise before it gets to the limiters. This can be accomplished by using a bandpass filter before the limiters.

The information in a RTTY signal is contained in a small band of frequencies centered around the Mark and Space frequencies. The interfering noise is spread over the whole bandpass of the receiver. (The actual spectrum of noise is dependent upon its source, the type of detector in the receiver, and the audio bandpass of the receiver.) For example, assume a typical "wide-shift" RTTY signal is being received in the presence of "white noise." The RTTY signal as it appears from the receiver will occupy, approximately, a bandwidth from 2125 to 2975 Hz (a bit wider because of keying rate and waveshape). The noise will occupy the frequency spectrum from, perhaps, 300 Hz to 3300 Hz.

If a bandpass filter is placed between the receiver and the TU, and its bandwidth is adjusted to be just wide enough to pass the RTTY signal, the noise getting into the TU will be reduced by a factor of four times! Generally, the improvement is even better because the noise coming from the receiver tends to be very strong at the lower audio frequencies and relatively weak at the higher frequencies where the RTTY tones are located. The limiter is not frequency dependent. Therefore, by eliminating the very strong low frequency noise components a great increase in receiving performance is gained. Incidentally, a major argument in favor of "narrow-shift" has just been made!

LOW PASS FILTER

The signal in the receiving loop is supposed to consist of on and off pulses of 22 millisecond duration, minimum. When noise is present, the loop may open and close erratically at intervals of less than 22 ms; this can "junk" copy. The effect of noise can be reduced by somehow restricting the speed at which the loop can open and close (change from M to S to M). This can be accomplished by placing a low pass filter between the detector (in the TU) and the loop keyer. In the case of the Twin City TU described last month, it would go somewhere between the outputs of the voltage doubler rectifiers and the polarized relay.

LOOP KEYER

The output loop should be either open or closed (S or M) and nothing in between. When it is opened, the current in the loop should decay rapidly, and when it is closed, the current should build up very rapidly. (Preferably 1 ms or less). This problem will be discussed in Parts 15 and 16.

The Twin City TU contains a polarized relay that keys the output loop. The relay contacts are either open or closed, thus meeting the criterion that no "half-way" state exist. So long as the power supply feeding the loop is at least 130 volts and so long as there are not too many selectors in the loop (2 is enough), the current rise time will be satisfactory. Therefore, the output loop is indeed theoretically very good. However, it does have three drawbacks: 1) The polarized relay is a precision device and must be carefully and accurately adjusted (An I-193C test set will do this), 2) The contacts on the relay may generate noise that is difficult to eliminate, and 3) Some people just hate polar relays (prejudice).

The relay can be replaced with devices such as vacuum tubes or transistors, but when this is done two criteria must be met: 1. Only two states must exist in the output loop, on and off, and 2. The current rise and fall times must be short; i.e., 1 ms or less.

The second criterion is easy to meet. One method is to use at least a 130 volt loop power supply (and a transistor that is capable of working at 130 V or higher). A better, but more complex, solution is to use a "constant current mode" device or devices to key the loop.

The first criterion has to be considered because vacuum tubes or transistors can operate in a partially-conducting state. A relatively simple way to meet this criterion is to place an electronic "switch" immediately preceding the output device. Usually, a Schmitt trigger is used. It is a circuit whose output is either "on" or "off" although the signal applied to its input may have any value.

SUMMARY

Three basic improvements can be made to the "basic" TU described in Part 8. They are, in order of decreasing importance: 1. A bandpass filter placed be-

fore the limiter in order to reduce the amount of noise appearing at the limiter. 2. A low pass filter placed after the detector and before the output keyer; the filter reduces rapid opening and closing of the loop when noise is present, and 3. An electronic loop keyer to replace the polarized relay; the keyer must include a switch before it and the keyer must have the right time constants

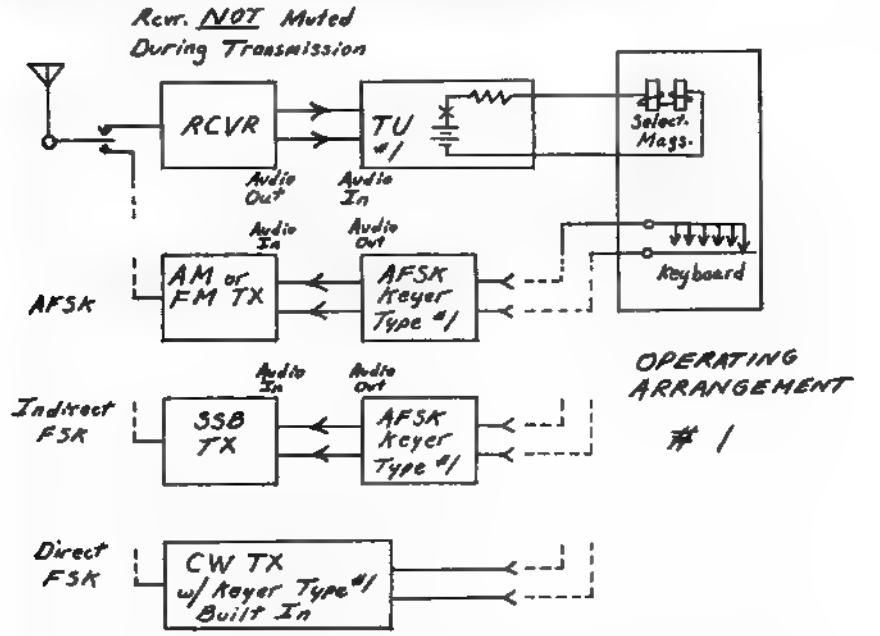
Part 10 - EQUIPMENT INTER CONNECTION

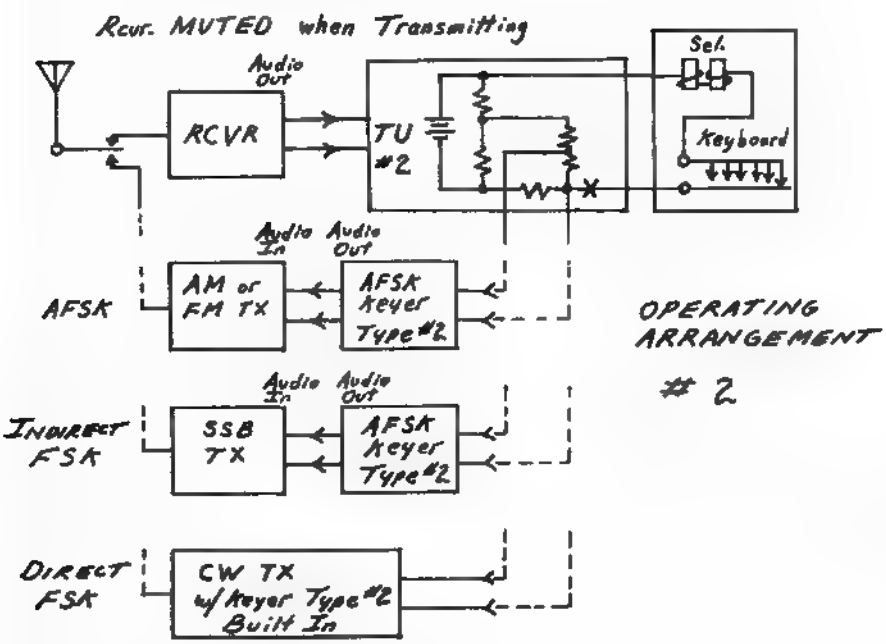
In order to discuss FSK generation and FSK keyers, it is necessary to give the basic station operating details and the method of interconnection of the various pieces of station gear.

OPERATING ARRANGEMENTS

There are two basic ways to interconnect the equipment and to operate a station: 1) Connect the output of the receiver to a terminal unit (TU) and connect the output of the TU to the printer. Connect the keyboard to a keyer and connect the output of the keyer to the transmitter. 2) Connect the output of the receiver to the input of the TU and connect the output of the TU to the printer and the keyboard. Connect the keyer input into the loop containing the keyboard, the TU, and the printer, and connect the keyer output to the transmitter.

In arrangement #1, the message being sent is printed locally by leaving the receiver on and tuning it to the transmitter. This arrangement is ideal when running AFSK on VHF FM because FM receivers are normally not muted while transmitting and the receiver doesn't overload. The "local" copy is obtained "off the air" and thus serves as a good check that something is really being sent. The arrangement might create problems with VHF AM because the receiver might get unhappy with the strong signal. Also, if the transmitter and receiver are on two different frequencies, it requires re-tuning the receiver.





In arrangement #2, the receiver is muted while transmitting. Local copy is obtained directly from the keyboard because the keyboard and printer are in the same loop. The receiver does nothing but receive the other station, so it can be left tuned to the frequency. The major objection to this arrangement is that since copy is from the transmitting loop and not from "off the air", you have no really good check that the transmitted signal is really being transmitted. (We have many times copied ten minutes of steady Mark because someone was making local loop copy, but never connected the local loop into the transmitter!)

RECEIVING EQUIPMENT INTERCONNECTION

Next, let's look at the actual interconnection of the station equipment. For either arrangement #1 or #2, the audio output of the receiver is connected to the input of the TU; this interconnection merely feeds the audio tones coming out of the receiver into the TU. The receiver output can be obtained from the loudspeaker terminals or from a headphone jack. It is nice to have the loudspeaker operating because listening to the tones can signal (to the operator) when something has gone wrong (like QRM). However, the constant audio tones can sometimes make one ready for the "funny farm" after an hour or so of listening (XYLs are especially annoyed by the tones). Also, the loudspeaker tends to act as (like) a microphone and it can pick up enough noise from the printer to "junk" copy.

For either arrangement #1 or #2, the output of the TU is connected into a series loop composed of a 130-volt (or higher) dc power supply, a variable resistor, and the selector magnets. The TU opens and closes the loop. Some TUs built in (TT/L-2, ST-5, ST-6) and others require a separate loop supply (CV-89). Obviously, if the dc loop supply is built into the TU, you merely connect the selector magnets to the TU. For most teleprinters, the selector magnets require 60 mA during a steady Mark. The current can be adjusted by means of a series rheostat (2 to 4K, 25W) or by varying the screen voltage on the output tubes. If arrangement #2 is used, the keyboard contacts are also included in the loop (in series with the printer, TU, and power supply), and the keyer must somehow be connected into the loop. (Units like the TT/L-2, ST-5, and ST-6 have a jack for extracting a voltage for operating the keyer.)

With the arrangements described, it should be possible to copy signals regardless of whether you can or want to transmit. Also, the arrangements are independent of whether you want to receive AFSK or FSK. In either case, the receiver must provide at its output an AFSK signal having the frequencies required by the TU.

TRANSMITTING EQUIPMENT INTERCONNECTION

For transmitting the options become numerous depending upon whether you want to transmit AFSK, indirect FSK (AFSK into an SSB transmitter), or direct FSK and depending upon whether the keyer is to be operated directly from a keyboard (arrangement #1) or indirectly from a TU (arrangement #2).

Take the latter pair of options first. With arrangement #1, the keyer is operated directly from a keyboard; that is,

the keyboard is connected directly to the keyer input and nowhere else. Arrangement #2 requires that the keyer get its input signal from the TU (a terminal or jack must be available within the TU to provide the necessary keying voltage). The input circuit of the keyer (be it AFSK or FSK) is different depending upon whether it was designed for direct operation from a keyboard or indirect operation from a TU.

Assume that you want to transmit AFSK. Connect the output of the keyer to the audio input (microphone input) of the FM or DSB AM transmitter. When something is "typed" on the keyboard, the keyer output will contain an audio signal with a warbling (tweedling), characteristic. When nothing is being "typed", a steady audio tone should appear at the keyer output.

If indirect FSK is to transmitted, connect the audio output of an AFSK keyer to the microphone input of a single sideband transmitter. You must be careful to make sure that the SSB transmitter has adequate carrier and unwanted sideband suppression. The keyer must not overdrive the SSB transmitter. The keyer must have an audio output free harmonics. Don't burn up the transmitter (or its power supply); you are running constant audio into the transmitter.

If indirect FSK is to be obtained by applying AFSK to an SSB transceiver, the comments applying to an SSB transmitter also apply. Only arrangement #2 can be used. In addition, a frequency offset might give troubles. A recent article (Ken Ridout, WB5FHF, RTTY Journal, 1973 DEC. p. 17) describes the problem and gives a solution.

If direct FSK is to be employed, an FSK keyer must be built into the transmitter. (Some come with the keyer built in.) The FSK keyer is connected to the oscillator circuit in the transmitter or VFO. Two different (although similar) circuits are used depending upon whether the keyer is to be operated directly by the keyboard (arrangement #1) or indirectly from the keyboard via the TU (arrangement #2).

In Part 11, we will give the theory of indirect FSK and the circuits for direct FSK.

SUMMARY

There are two basic ways to operate a RTTY station. Arrangement #1 makes local copy by actually copying the signal transmitted. The receiver is not muted while transmitting. The receiver is connected to the TU which is connected to the printer. The teleprinter is "split". The keyboard is connected to the keyer which is connected to the transmitter. Arrangement #2 makes local copy by copying directly from the keyboard. The receiver is muted during transmission. The receiver is connected to the TU. The keyboard, printer, and keyer are connected to the TU output. The keyer is connected to the transmitter. The input circuit of the keyer (and to some extent, the keyer itself) is different depending upon whether arrangement #1 or #2 is to be used. For AFSK, an external AFSK keyer is used with an FM or DSB AM transmitter. For indirect FSK an external AFSK keyer is used with an SSB transmitter. For direct FSK, an FSK keyer is built into the transmitter.

Part 11 - GENERATING AN FSK SIGNAL

We have described the basic equipment interconnection necessary for transmitting a RTTY signal. Now, we will go into the details of how an FSK signal is generated.

There are two ways to generate an FSK signal:

A) Indirect FSK is obtained by applying an AFSK signal to the audio input of an SSB transmitter.

B) Direct FSK is generated by modifying the oscillator circuit of a transmitter or VFO so that its frequency can be shifted by the signal from a keyboard.

A. Indirect FSK

An AFSK signal consists of one of two audio tones; e.g. a 2125 Hz tone exists when a Mark is sent and a 2295 Hz tone exists when a Space tone is sent. If the Mark tone (2125 Hz) were applied to a DSB AM transmitter, the output from the transmitter would consist of three frequencies, the carrier, the carrier plus 2125 Hz (the upper side frequency), and the carrier minus 2125 Hz (the lower side frequency). If the Space tone (2295 Hz) were applied to the transmitter audio input, the output would consist of the carrier, the carrier plus 2295 Hz (the upper side frequency), and the carrier minus 2295 Hz (the lower side frequency). If the tones were applied alternately (a Teletype signal), the transmitter output would contain the carrier, an upper sideband (carrier plus 2125 Hz and carrier plus 2295 Hz), and a lower sideband (carrier minus 2125 Hz and carrier minus 2295 Hz). If the carrier and the upper sideband were somehow deleted (LSB, SSB), the only signal left would be two frequencies - the carrier minus 2125 Hz and the carrier minus 2295 Hz - this is an FSK signal (including the proper "sense").

B. Direct FSK

The output from a CW transmitter consists of a single frequency. The output frequency can be shifted downward by applying a small capacitance (ca. 3 pF) across the tuned circuit in the oscillator (usually from the oscillator tube cathode to ground). If the small capacitor can be connected and disconnected according to the Spaces and Marks, respectively, in a RTTY signal, then an FSK signal is generated. The most difficult problem with direct FSK generation is the requirement to shift a small capacitance in and out of a radio frequency circuit. Although it would appear that the small capacitor could be simply placed in series with the keyboard contacts and the combination placed from cathode to ground in the oscillator circuit, this arrangement would not work because the capacitance associated with the keyboard contacts and the leads from the keyboard to the oscillator would contain far too much capacitance. Also, the RF in the leads to the keyboard would cause problems. In addition, the keying would be "upside down" because the capacitor is to be added when the contacts are open (Space).

Therefore, the capacitor must be switched by "remote control", as it were. The actual circuit used depends upon whether 1) The FSK signal is to be actuated directly from a keyboard or 2) From a voltage developed in a loop associated with a TU. (In Part 10 these were referred to as arrangements #1 and #2, respectively.)

1) Direct FSK from a Keyboard

In Figure 1 is shown the circuit to be added inside the VFO or the transmitter. The basic theory of operation is that when the diode is not conducting (Mark), the entire circuit is assumed to not be present and the oscillator operates at its nominal frequency. When the diode is conducting (Space), the series combination of C1 and C2 is placed across the oscillator circuit and the frequency of oscillation is shifted downward. The radio frequency chokes (RFC1 and RFC2) isolate the diode dc biasing network from the diode and its capacitors (C1 and C2).

When the keyboard contacts are closed (Mark), the top end of the diode is dc grounded and the lower end of the diode has approximately plus 8 volts on it due to the dividing action of R2 and R3. Therefore, the diode is reverse biased and does not conduct thus effectively removing the capacitors (C1 and C2) from the circuit.

When the keyboard contacts are open (Space), plus 105 volts dc is applied to the upper end of the diode via R1 and plus 8 volts is applied to the lower end of the diode due to the dividing action of R2 and R3. Thus the diode conducts and effectively connects C1 and C2 to the oscillator, lowering its frequency. The amount of shift is determined by the setting of C2.

There are several notes of caution that should be observed with the direct FSK circuit just described; these cautions also apply to the circuit to be described later. The circuit contains radio frequency energy. Therefore, the actual partsand their placement are important. C1 and C2, and the diode should be mounted as close to the oscillator cathode as possible. Both RFC1 and RFC2 must have low internal capacitance and low capacitance to surrounding objects. RFC2 shunts C2, and if the capacitance from RFC2 is too high it will result in a shift that is too wide and C2 will become ineffective. The resistors should be mounted away from the diode and C1 and C2. RFC1 and RFC2 are to be physically located between the two portions of the circuit and as far from the chassis and chassis bottom plate as possible. The bypass capacitor, C3, is used to keep the oscillator RF out of the keyboard and any RF from the transmitter output from getting back into the VFO via the keyboard leads. C3 should be mounted at the point where the lead from the keyboard enters the VFO/transmitter chassis/cabinet. For example, if a jack is mounted on the chassis (to permit disconnecting the keyboard from the VFO/transmitter), the 0.001 UF bypass (C3) should be mounted on the jack. Also, there should be nothing within the teleprinter connected across the keyboard contacts; all filters, capacitors, etc., must be removed. The only thing connected across the keyboard contacts is to be C3, and that is to be located as indicated above.

2) Direct FSK From a TU

In terminal units such as the TT/L-2, ST-5, and ST-6, a keying voltage is provided. (Remember that we are now talking about arrangement #2 where the printer and keyboard are in the same loop along with the TU and the loop power supply. Local copy is made directly from that loop. The received is disabled during transmission.) Within the TU's a circuit is provided that samples the loop current;

when a Space is present, a positive voltage of about 40 volts appears on the FSK terminal; when a Mark is present, a negative voltage of about 40 volts is present. (The method for obtaining the voltage will be given in Part 12.),

Figure 2 shows a typical direct FSK circuit for use with a TU providing a keying voltage. When the TU loop is in Mark, the voltage applied to the keyer is minus 40 volts, the diode is reversed biased, and C2 is disconnected from the oscillator cathode circuit, thus giving the normal carrier frequency. When the TU loop is in Space, the voltage applied to the keyer is plus 40 volts, the diode conducts, thus connecting the capacitor C2 across the oscillator circuit and lowering the frequency.

The comments made previously about care in mounting the components within the VFO/transmitter apply equally well to the circuit in Figure 2. Make sure that C3 is across the lead coming from the TU at the point where the lead enters the VFO/transmitter chassis.

Additional Direct FSK Notes

In both circuits given, the amount of shift is dependent upon the capacitance switched in and out by the diode. Some capacitance is added just simply by adding the components. Therefore, if the VFO was precisely calibrated before the FSK circuit was added, its calibration will now be off. The width of the shift is dependent upon the capacitors added as well as by the strays added. The shift can be varied by varying the variable capacitor, C2. If only one shift is to be used and only on one band, C2 can be set once and forgotten. If variable shift is desired, C2 will have to be changed

If the VFO is followed by a multiplier on some bands, the shift will change with the multiplication. This will necessitate readjusting C2.

If many different shifts are desired or required, they can be obtained by placing a potentiometer in the shifting circuit to control the amount of dc in the diode during Space, thus controlling the conductivity of the diode. The diode does not fully conduct when a Space is sent, the amount of capacitance switched in is not the full amount available and thus the frequency shift is less than the maximum amount. Also, by using a rotary switch, and several pots, each pot can be set for the desired amount of shift for a given band, etc., and just the switch is operated to select the shift desired.

The circuits given in Figures 1 and 2 turn the diode fully on and off - a method that appears to be much less critical of diode characteristics and temperature than does the partially-conducting shift pot method.

Because the FSK circuit (Figures 1 or 2) is to be added inside a transmitter/VFO, the components might not be the exact values required. The following bibliography lists information appearing in the RTTY Journal for specific transmitters.

Transmitter FSK Information Appearing in the RTTY Journal from 1946 thru 1974:

Central Electronics 100V, 200V: 1968 FEB pp. 3-5, 1968 MAR p. 2, 1969 JAN p. 14
Collins 32V: 1964 SEP pp. 10-11, 1966 JUN pp. 2-8, 1969 MAY pp. 5-6.
KWM-2: 1967 - OCT pp. 3-7.
KWS-1: 1972 FEB p. 13.
S line/KWM-2: 1965 JUN p.8..
32-S1 & KWM-2: 1965 AUG pp. 6-7, 1965 DEC p. 13.
Drake T4X: 1968 MAY p. 3, 1970 OCT. p. 2, 4B, 1970 DEC p. 9, 1971 APR. p. 9.
Hallicrafters HT32A: 1965 FEB pp.8-10, 1966 JAN pp 12-13, 1966 JUN pp. 2-8,
HT 44: 1966 FEB pp. 2-3.
Heath DX-60A: 1968 NOV p. 7 (reprint 1972 NOV pp. 9, 16), 1971 MAY pp. 13-14 DX 60 B
HW-16: 1967 DEC pp. 2-3.
Marauder: 1970 JUN pp. 13-14.
SB series: 1972 OCT pp. 2-3, 1973 DEC p. 17.
SB-101: 1972 OCT pp. 4-5.
SB-200, SB 102: 1966 APR p. 8.
SB-400: 1964 DEC pp. 12-13, 1965 MAY p. 13, 1966 JUN pp. 2-8.
SB-401: 1970 FEB pp. 7, 14.
Johnson Invader 200: 1972 APR pp. 15-16.
Ranger, Navigator, Valiant: 1968 JAN. pp. 4-7. Kenwood
Military ART-13: 1965 JUN pp. 4-6.
BC-221 Q: 1966 JUN p. 3.
Swan 240 - 350: 1966 APR p. 7, 1968 OCT p. 18, 1969 JAN p. 4, 1971 MAR pp. 2, 13.
General Information: 1964 NOV p. 7, 1965 FEB pp. 8-10, 1965 OCT pp. 8-11, 1967 FEB pp. 3-4, 1967 SEP p. 12, 1967 DEC pp. 4-7, 14, 16, 1968 FEB pp. 6-7, 20. 1968 APR p. 13, FEB pp. MAY pp. 13-14.
Central Electronics 100V & 200V: 1973 JUL-AUG, p. 7.
Drake 4B: 1974 NOV, p. 20.
Heath DX60B: 1973 SEP, pp. 3-5.
Heath SB-102: 1973 MAR, p. 12; 1973 APR, p. 10; 1973 SEP, p. 6; 1973 DEC p. 17.
Kenwood R-599: 1973 SEP, p. 7, p. 13; 1974 MAR, pp. 5-6.
TS-900: 1974 NOV, p. 15.

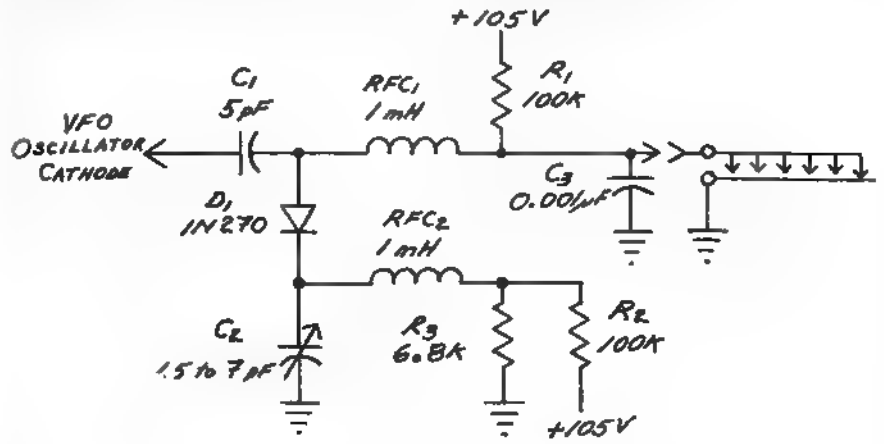


FIG. 1

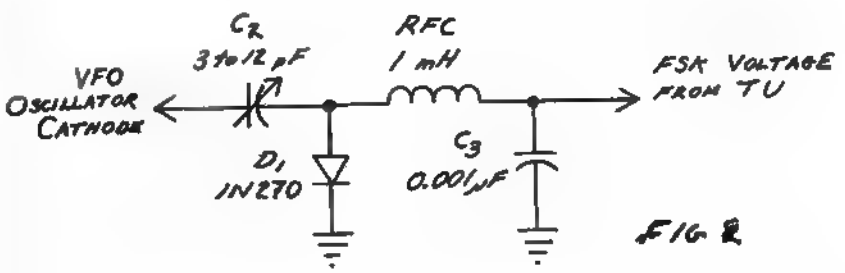


FIG 2

Part 12 - LOOP SUPPLIES AND KEYING VOLTAGES

In the last two parts we have been discussing methods of keying a transmitter. In what was called Arrangement #2, it was necessary to obtain from a loop the voltages used to operate the keyer (FSK or AFSK). Now, we will discuss the circuit used in such units as the TT/L-2, ST-5, and ST-6 to obtain (or provide) the necessary keying voltages. We will also discuss loop power supplies in general in order to define the requirements for a loop supply and we will give a typical circuit for a loop supply.

LOOP SUPPLIES

The basic requirement for a loop supply is 130 to 260 volts dc. It must be capable of continuously supplying that voltage at 60 mA. There is no real upper or lower limit to the supply voltage. Below 130 V, time constants in the loop might become troublesome. Above 260 volts, the voltages start becoming rather hazardous. (Even 130 volts can be lethal, but the danger increases as the voltage increases.) "Real" telegraph loops usually work at 260 volts.

The reason that the voltage, per se, is not too important is that the loop is made to operate at a specific current, usually 60mA. Therefore, once the supply is built and operating, you place resistance inseries with the loop to set the current at the desired level. The higher the voltage, the higher the resistance required and the more power "wasted" in the series resistance. However, because of time constant problems, the more power wasted in the resistance, the better the loop characteristics! (See Parts 15 and 16.)

If you have more than one loop, you can use two different approaches to supplying them.

1) Build a separate power supply for each loop, or 2) Build one supply that is large enough to handle all loops at once. The advantage to several "small" loop supplies is that they can be "floated" (isolated or not grounded) and this can be used to advantage for

keying other loops, etc. (to be described later). The approach used here was to build one big supply (130 V, 1 A), ground the negative terminal, and run whatever is desired from it.

If you intend to build a TU such as the ST-5 or ST-6, you can buy the power supply components for it now and build a loop supply. Later, you can cannibalize it and reuse the parts in the complete TU. This is a very economical approach. (For the ST-5 power supply see: RTTY J., 170 MAY p. 7; for the ST6: RTTY J., 1970 SEP, p. 11.)

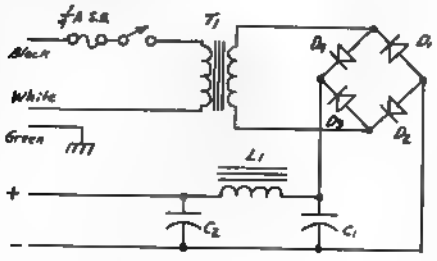


Fig. 1

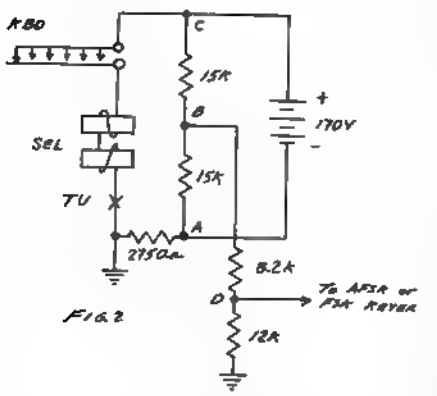


Fig. 2

If you want to build one from scratch, you might try the circuit shown in Figure 1. Basically, it is a simple full-wave bridge rectified supply with capacitor input filtering. The transformer is a simple "isolation" transformer. The advantage of using an isolation transformer is that it can always be used for its original purpose if you no longer want it for a loop supply. Suitable type numbers are: Allied 6K112HF, 6K38VCP; Essex (Stancor) P-6410; TriadN-51X, N-68X. These are all 35 or 50 VA transformers. Many are available in higher power (VA) ratings.

For the rectifiers, the old standby 1N4005 is an excellent choice. If you want a bridge assembly (all four diodes in one blob), try the Motorola HEP177 (280 Vrms, 1A), Mallory FW-600 (600 PRV, 2A), or the International Rectifier 18DB4A (282 Vrms, 1.8A). These packages are in the $2 price range.

If you use one of the transformers listed (or a higher VA rating transformer), you should use capacitor-input filtering as shown. For the input capacitor, C1, try 20 uF or higher at 200 or 250 Vdc. The capacitor size will control the output voltage. For the output filter, C2, use something in the 500 uF range, or higher. We have used the Mallory HC20005 (500 uF, 200 V). The Sprague 142F200BC (1400 uF, 200 V) will work nicely.

For L1, a 2H choke rated at 60 mA or higher should be used. The Allied 6X19HF, Essex (Stancor) C2325, or the Triad C-21X should be adequate; they are rated at 200 mA dc or higher.

You can try using an old TV set power transformer. Unfortunately, they are usually rated at voltages a little higher than really desired. By using one in a conventional full-wave, center-tapped circuit with a choke input filter, it might be possible to get the voltage low enough to be suitable. If you use a choke-input filter, make sure that there is a load across the output at all times (a bleeder) because the output voltage tends to get quite high under no load. A simple wire wound resistor drawing 10 to 20 mA should be suitable.

KEYING VOLTAGE FROM A LOOP

In the two previous installments of this series we described two different operating philosophies or equipment arrangements. In Arrangement #2, the output of the TU was placed in a loop containing the keyboard, the selector magnets, the loop supply, and a current limiting or adjusting resistor. When transmitting, the receiver is muted. When "typing" on the keyboard, the printer gives copy "direct" from the keyboard. The keyer (FSK or AFSK) is operated from this loop.

The means of obtaining the keying voltage from the loop is shown in Figure 2. A 170 volt dc power supply is connected in series with the keyboard, the selector magnets, the output device in the TU (indicated by an X), and a current limiting resistor (2750 ohms). When the loop is closed (Mark), point C is nearly at ground potential and point A is at about - 170 volts. The midpoint of the two 15K resistors, point B, is at about -60 volts, and point D is at about - 40 volts. When the loop is opened (Space) by either opening the keyboard contacts or by the TU, point A is at nearly ground potential and point C is at about plus 170 volts. Therefore, point B is at plus 60 volts, and point D is at about plus 40 volts.

The -40 volts at point D during Mark and the plus 40 volts at point D during a Space is supplied to the keyer (for example, in FSK keyer given in Part 11 in Figure 2) and the keyer thus keys according to the Marks and Spaces in the loop.

Part 13 - GEARS AND THINGS

Unlike the code used for hand-keyed telegraphy with its variable-length characters, the Murray code used with amateur printing telegraphy (Teletype) has a fixed-length format; i.e., all characters be they the letter E or the letter Y, are of the same length. This fixed-length format is related to operating speeds within the machines.

Teleprinters, when arranged to communicate with each other, are connected in a series circuit called a loop. That is, the keyboard contacts and the selector magnets are in series. Power is supplied to this series circuit by means of a dc power supply of at least 130 volts. A resistor is inserted into the loop to limit the current to 60 mA.

A character is sent by depressing a key on the keyboard. When the key is depressed, contacts within the machine open and close in a predetermined pattern at a fixed rate. (See Part 2 for the code format.)

The actual character is composed of five time intervals during which the circuit is either open or closed. The condition when no current is flowing (contacts open) is referred to as a Space (S). When current is flowing, it is called a Mark (M). Each M or S is approximately 22 milliseconds (ms) long. Each character is preceded by a Space, called the Start pulse. Each character is followed by a Mark, called the Stop pulse.

With Bell System machines running at so called "60 Speed", the Stop pulse is 31 ms long. The Start pulse and the five character elements are 22 ms long. Therefore, it takes 163 ms for every character. A "word" is defined as 5 characters and a character space. Therefore, it takes 6 times 163 ms or 978 ms (0.978 seconds) for one word. The number of words per minute is 60 (1 minute equals 60 second) divided by 0.978 which equals approximately 61.3 words per minute (WPM). Therefore, a Bell System teleprinter operating at its maximum speed will print 61.3 words per minute; this is called "60 Speed" operation.

With Western Union machines, the code is the same as for Bell System machines (the only difference being that the apostrophe and bell are interchanged). However, the Stop pulse is only 22 ms long with a Western Union machine (vs. 31 ms with a Bell System machine). Therefore, a W. U. machine character takes 7 times 22 ms equals 154 ms. A word takes 6 times 154 ms equals 924 ms or 0.924 seconds. Dividing 60 (seconds per minute) by 0.924 gives 65 words per minute.

In spite of the different operating speeds in words per minute, the two machines are perfectly compatible.

The next item to consider is the speed at which various things within a teleprinter operate.

In the U.S., commercial ac power is generated at exactly 60 Hz. Therefore, an 1800 RPM synchronous motor will operate at exactly 1800 RPM. Ditto for a 3600 RPM synchronous motor.

Because the transmitting shaft (the keyboard shaft), the receiving shaft (the selector shaft), and the motor are geared, they must always revolve at constant relative speeds. So long as a synchronous motor is used, they also rotate at constant absolute speeds. Because gears must have an integral (whole) number of teeth, only certain speed ratios are allowed. One revolution on the transmitting (keyboard) shaft corresponds to one character. If you lift the lock loop on the transmitting shaft or depress the repeat key, the machine will continuously transmit a character at machine speed. On a Bell System machine, one character takes approximately 0.163 seconds; therefore, the transmitting shaft should rotate at 1/0.163 revolutions per second or 60/0.163 RPM which equals 368.1 RPM. Assuming that the motor is a synchronous motor operating at 1800 RPM, the gear ratio from the motor to the transmitting shaft must be close to 1800/368.1. The closest integral ratio is 1800/367.5 which is 30/7 times 24/21; 367.5 RPM is 367.5 characters/minute which equals exactly 61.25 WPM. (The reason for a double ratio such as 30/7 times 24/21 will be explained later; it is related to the mechanical power train sequence within a machine.)

On the Western Union machines, the ratio desired is 60/0.154 or 389.61 RPM. The closest gear ratio to 1800/389.61 is 30/7 times 13/12. Therefore, with a motor speed fixed at 1800 RPM exactly, the transmitting shaft will revolve at 387.6923077 RPM which will give a speed of 387.6923077 characters/minute or 64.61528 WPM or Mark and Space time intervals of 22.10884 ms.

When receiving a RTTY signal, the receiving shaft operates continuously. However, the "decoding" mechanism on that shaft does not run until the Start pulse is received; the mechanism on the receiving shaft then rotates until the code elements have been received. Because the receiving cam does not have to rotate for the entire character interval, but only during the start pulse and the five intervals that contain the character code, the receiving shaft can run faster than the transmitting shaft.

There is a subtlety involved here. If the two machines are not running at exactly the same speed, then the receiving shafts must run faster than the transmitting shafts. If they did not, the receiving machine that was running slower would fall behind. Machines had to be designed to run at slightly different speeds because when the machines were first designed and built, governor-controlled motors had to be used because either only dc power was commercially available or the commercially available ac power was not frequency stable. (This leads into a long, perhaps, interesting, discussion about electric clocks, synchronous converters, constant voltage transformers, etc.) Also, if machines are operating at exactly the same speeds, and the transmitting and receiving shafts are also operating at the same speeds, and one machine gets out of step with the other, they can never get back into step. However, if the receiving shaft is running faster than the transmitting shaft and stops at the end of each character, then if they get out of step, they can resynchronize within a few characters.

Anyway, the receiving shaft has to run faster than the transmitting shaft. The receiving shafts in both Western Union and Bell System machines run at exactly 420 RPM. With an 1800 RPM synchronous motor, a gear (actually a pinion-gear combination) ratio of 30/7 will give exactly 420 RPM from 1800 RPM. Not only do W.U. and Bell machine receiving shafts run at the same speeds, but the selector mechanisms are identical. Hence, the machines are perfectly compatible because their selectors are identical!

One further note on the gear ratios. Within a TTY machine such as the Model 14 and 15, the motor drives the receiving shaft. For "60 speed" (61.25 WPM, Bell; 65 WPM, W.U.), the receiving shaft must run at 420 RPM. Therefore a gear ratio of 30/7 is always used between an 1800 RPM synchronous motor and the selector shaft. The transmitting shaft is run from the receiving shaft. (A jack shaft may be used between the receiving shaft and transmitting shaft.) The gear ratio between the receiving shaft and the transmitting shaft is fixed dependent upon whether the transmitting shaft has a 7-unit cam for W.U. format or a 7.42 unit cam for Bell format. The ratio is 39/36 on a W.U. machine and 24/21 on a Bell machine. With a Model 28 for Bell System operation, the 3600 RPM motor has a 14-tooth pinion driving a 96-tooth gear on a jack shaft. The jack shaft has a 48-tooth gear which drives a 60-tooth gear on the selector shaft. This combination gives a 60/7 ratio which results in a selector shaft speed of exactly 420 RPM from the 3600 RPM motor. The selector to keyboard shaft gear ratio is the same 24/21 as on Bell System Model 14 and 15.

Because the gear ratio between the receiving shaft and the transmitting shaft is set according to the cam format on the transmitting shaft, these gears should never be changed. However, if the motor speed or operating speed is to be changed, then the gear ratio between the motor and the receiving shaft is to be changed.

When changing speeds, while still using the Murray code, only the motor or selector shaft speed is to be increased because the transmitting shaft speed will change accordingly. However, a sad fact of life is that essentially no one except amateurs are using the Murray code. Commercial operation is now at 100 or 150 WPM. You cannot speed up your machine to 100 or 150 WPM operation and expect to copy the commercial stations because they use an entirely different code! The trouble with the Murray code is that is contains only 5 code elements and that means only 32 characters are possible without shifting. The commercial users are using the ASCII (American Standard Code for Information Interchange). This code contains 7 code elements, giving 128 characters without shifting (and twice that many with shifting).

The ASCII code and its details can be found in the IT&T Handbook (Reference Data for Radio Engineers, 5th ED, Howard Sams). It is a 7-element code, plus a start pulse, a stop pulse, and a parity pulse. For 100 WPM operation, the stop pulse is two units long, resulting in 11 units per character. The units are 9.09 ms long. The 150 WPM version is the same except the stop pulse is only one unit long, giving a 10 unit character with 6.66 ms long units.

See RTTY, 1969 JUL-AUG, p. 4 for speed information on the amateur Murray code and p. 11 for motor-selector shaft gear information.

We would like to acknowledge the assistance of Clarence Kersker, WA8AYS, and Dave Goodman, WA8UIT, who dug into the innards of machines to count gear teeth.

Part 14 - RTTY TUNING INDICATORS

The following is not meant to be an exhaustive discussion of tuning indicators, but it will give some thoughts about ways to indicate the tuning status when receiving a RTTY signal.

There are at least three ways to indicate tuning of a receiver when trying to copy a RTTY signal: 1) A display on an oscilloscope of the demodulated signal versus time, 2) A cross as viewed on the face of a cathode ray tube, and 3) A zero indicating meter.

Before discussing how to connect a tuning indicator, a brief discussion of TUs is in order. The figure shows the "heart" of most audio-type TUs.

Basically, the operation is as follows. The tones coming from the receiver are run thru a limiter and amplifier. The audio output from the limiter/amplifier is coupled thru the two resistors, R, into two tuned circuits. The resistors are made fairly high in value to preserve the Q of the tuned circuits and to isolate them as much as possible. One of the tuned circuits is tuned to the Mark frequency and the other to the Space frequency.

Because the tuned circuits are parallel resonant, an audio voltage appears across only one tuned circuit at a time, and only when the frequency of the signal is at or near the resonant frequency of that tuned circuit. Thus, when a Mark tone is received an audio voltage will appear across the Mark tuned circuit and none (or very little) across the Space tuned circuit. When a Space tone is received, just the opposite will occur.

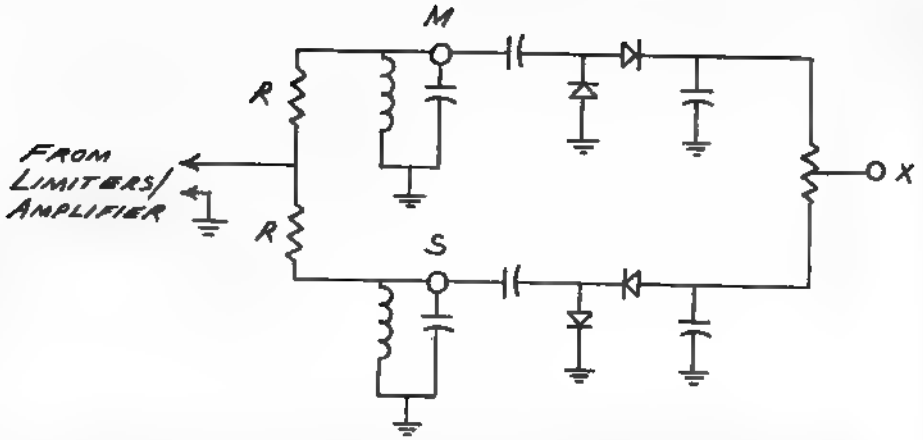
The voltage appearing across a tuned circuit is rectified using the same type voltage doubler commonly used in power supplies. The diodes connected to one tuned circuit are reversed from those on the other tuned circuit. In this example, a Mark tone results in a voltage across the upper tuned circuit and this voltage gives a positive dc voltage at point X. A Space tone results in an audio voltage across the Space tuned circuit and this results in a negative dc voltage at point X.

The voltage at point X will be a replica of the signal in the transmitting loop at the sending station and will be in polar form. The voltage at this point is used to key the output loop thru a dc amplifier ("keyer" tube or transistor) in a simple TU, or it can be processed thru various circuits such as a low pass filter, a level decision making stage, etc., before keying the output loop

1) Perhaps the best tuning indicator from the standpoint of obtaining the maximum amount of information about the signal being received employs an oscilloscope arranged to give the demodulated signal as a function of time. For this you will need a dc coupled capability and a triggered sweep. The signal displayed will, ideally, be that pictured in a handbook showing a RTTY character. You can obtain such a display by connecting the scope input to point X in the figure. At this point, the signal has not been cleaned up by the circuits within the TU that prepare it for keying the output loop. Therefore, all noise and other forms of trouble making voltages will appear on the display. Perhaps the least desirable feature of this method of tuning is that it will provide a lot of information about the signal, and perhaps too much! One of the most interesting features is that it shows all the "crud" generated in the keyboard contacts of the transmitting station.

2) An oscilloscope can be connected to a TU in such a way that a "cross" pattern results when a RTTY signal is received. Adjust the scope for use with an external horizontal input. Connect the frame of the scope to the "ground" or common point on the TU, the vertical input to point "M" in the diagram, and the horizontal input to point "S".

Because the internal sweep is disabled, an ac voltage applied to the vertical input will give a vertical line; an ac voltage connected to the horizontal input will give a horizontal line. Ideally (for the purpose of scope display), the Q of the tuned circuits in the



TU should be as high as possible. When a Mark signal is received, a vertical line will appear on the oscilloscope, because an ac voltage will appear across only the Mark tuned circuit. When a Space tone is received, a horizontal line will appear. If the oscilloscope is properly adjusted, the height of the Mark vertical line will equal the length of the Space horizontal line.

When a RTTY signal is received, the scope will show the horizontal and vertical lines alternately, and this will appear as a cross. Once the scope is adjusted to give a proper cross on a properly-tuned signal, you can then use the scope as an aid in tuning a signal.

Several things can cause the pattern on the scope to be other than ideal. The Q of the tuned circuits should be low enough to give proper operation of the TU. This will mean that even when a Space tone that is on frequency is being received, a small voltage will appear across the Mark tuned circuit. Consequently, the horizontal line will actually appear as an ellipse; ditto for a Mark (vertically-oriented ellipse).

When a signal is being tuned in, size, position, and shape of the ellipses will change. Once you are familiar with such a tuning indicator the pattern will tell you how well tuned the signal is as well as such things as the shift of the signal being received in relation to the shift to which your TU is adjusted, etc.

3) Because the signal at point "X" is a polar signal, a zero-center meter connected from point "X" to ground will read approximately zero when a RTTY signal is received and properly tuned. This is somewhat analogous to the zero-center tuning indicator used on some FM receivers. When a steady Mark or Space is being received, the meter will not read zero. Therefore, this type indicator is best for use when a steady, machine speed (tape) signal is being tuned in. A VTVM adjusted for center zero can be used very satisfactorily in this application. Additional information about tuning indicators can be found in the following references:

RTTY FROM A TO Z, Durward J. Tucker, W5VU, Cowan Publishing Co. (CQ), 1970. p. 180 (Fig. 14.10). pp. 194-198.

THE NEW RTTY HANDBOOK, Byron H. Kretzman, W2JTP, Cowan Publishing Co. (CQ), 1962. pp. 145-156.

HAM-RTTY, W2NSD/1 & W4RWM, 73 Inc., 1963. p. 60. pp. 76-77.

It should be noted that there are two types of "cross-indicators". One type is as described above. The other was omitted because it required some (although very little) additional circuitry. Some of the references cited show how to build a complete RTTY tuning indicator that is independent of the TU. If you do not own an oscilloscope, you can build a special oscilloscope just for RTTY tuning indication. Such a scope is included in some of the references cited.

Another somewhat curious note: The three largest, and best-known amateur handbooks were checked for tuning indicator circuits - there were none!

PART 15 - TIME CONSTANTS IN TELEGRAPH LOOPS

The effects of time constants in telegraph loops will be discussed to show how they affect selector operation.

SERIES R, C CIRCUITS

When a series circuit composed of a resistance, R, a capacitance, C, and a DC source, V, are connected, a current I equals V/R flows at the instant of circuit closure. As time progresses, the current slowly decreases until it reaches O. The decay of current is governed by the product of R and C, and the current decays to 36.8% of its initial value in a period of time in seconds equal to the product of R in ohms and C in farads. The voltage across the resistor follows this same pattern; it starts at V volts at the time of circuit closure, decreases to 0.368V in RC seconds, and ultimately reaches O volts. The voltage across the capacitor starts at O volts, reaches (1-0.368)V equals 0.632V in RC seconds, and finally reaches V volts.

If, after the capacitor has charged to V volts, the battery is disconnected, the capacitor will remain charged indefinitely. When the circuit is closed with the battery removed, the capacitor will discharge and will reach 0.368V volts in RC seconds.

SERIES R, L CIRCUITS

In the case of a series R,L circuit there are some similarities and some differences from the R,C situation. For example, consider a simple series circuit composed of an inductor, L, a resistor, R, a battery of V volts and a switch. Assume that the circuit is sitting with the switch open; no current flows and the voltage across the resistor and inductor is zero. When the switch is closed, the voltage across the inductor immediately becomes V volts, but the current is still zero and the voltage across the resistor is also zero. The current slowly increases until it ultimately reaches I equals V/R amperes. The increase of current is dependent upon the ratio of L to R. The current reaches 0.632I in a period of time in seconds equal to L/R where L is in henries and R in ohms. The voltage across R follows the same pattern reaching 0.632V in L/R seconds, and the voltage across the inductor decays to 0.368V in the same L/R seconds.

A similarity between R,L and R,C circuits is they both have time constants; a difference is the R,C circuit time constant is proportional to R while the R,L circuit time constant is inversely proportional to R. Another difference becomes evident when the switch is opened. In the R,C circuit, as noted above, the capacitor can remain charged indefinitely; after the switch is opened, the voltage across the capacitor will remain at V volts until something is done to the circuit. In the R,L circuit the inductor can remain "charged" only so long as the current remains at I amperes, and this requires that the circuit remain closed. As soon as the circuit is opened, the inductor will "discharge". The "discharge" of the inductor, regardless of the circuit configuration, must obey the rule that the current thru the inductor cannot change instantaneously. This leads to two interesting situations:

1) Assume that the circuit is as described previously: A simple series combination of an inductor, a resistor, a switch, and a battery. Assume that the switch has been closed for a while and a steady current is flowing. If the switch is opened, current must cease, but the inductor will not permit it to cease instantaneously. Therefore, as the switch contacts separate, the inductor will react by generating a "back emf" of sufficient magnitude to break down the air gap between the contacts for a sufficient period to allow the discharge of the inductor; the air gap breakdown is evidenced by a spark. This sparking will, of course, eventually damage the contacts. A remedy is to provide some alternate path for the inductor discharge current. A device providing this path is known as a Contact Protection (C.P.) network.

2) Assume the circuit is the same as described previously, but in addition a C.P. net work composed of a series R,C circuit is placed across the contacts. (The mathematical analysis of this arrangement can become a bit much unless certain assumptions regarding component sizes are made; we will assume the appropriate values.) Because the C.P. network is across the switch contacts, it will have no effect upon circuit operation when the switch is closed; the closed or mark interval time constant time will be L/R, where R is the loop resistance. When the switch is open the total resistance of the circuit will be the sum of the loop resistance and the C.P. network resistance; call this total resistance, r. Therefore the open-switch or space interval time constant will be L/r. The spacing or "turn-off" condition resistance, r, is larger than the marking or "turn-on" condition resistance, R; consequently, the current decay at switch opening will be faster than the current build-up at switch closure.

A SELECTOR MAGNET LOOP

Consider the following series circuit: A 260-volt DC power supply, a teleprinter selector magnets, a resistor, and a set of metallic contacts with a C.P. network across them.

The selector magnets have some resistance and an inductance, L. The resistor is set to such a value that its resistance plus the resistance of the selector magnets is 4330 ohms. (This value will permit a steady-state current of 60mA to flow in the selector magnets.) Call the total loop resistance, R. (R equals 4330 ohms.) The metallic contacts can be either the keyboard contacts or the contacts on a polar relay. (We will consider driver tubes and transistors later.)

The magnetic pull exerted upon the armature by the selector magnets varies with the current flowing in the magnets.

When the contacts in the loop are closed the current will slowly build up and the magnetic pull exerted by the selector magnets will also build up. The rate of build up of magnet pull is dependent upon the L/R ratio of the circuit. When the contacts are opened the current will decrease and so will the pull of the selector magnets at a rate dependent upon the L/r ratio of the circuit during the open contact situation. Since the resistance of the circuit is higher during the open interval than during the closed interval, the armature will release faster than it operates; therefore, spacing bias is introduced into the printer mechanism.

The current decay time may be so short compared to the build up time that the decay time can be ignored. If this is true, the amount of spacing bias introduced into the printer is determined solely by the L/R ratio in the selector magnet loop. (It is assumed that the contacts are being operated by an unbiased source.)

Bias can cause troubles when receiving, especially when conditions are less than ideal. The "standard" land-line telegraph loops are 260-volt, 4330-ohm, 60-mA and 130-volt, 2170-ohm, 60-mA. Therefore, the manufacturer/designer of teleprinters designed the machines to give best performance when the selector magnets are inserted into these loops.

LOW-VOLTAGE LOOPS

With the advent of transistors, the 130-volt or higher loop was considered a real pain. This is especially true since 130-volt transistors are (or were) expensive (or non-existant). Because the actual voltage across the selector magnets when energized is typically 12 volts or less, there is a temptation to run the selector magnets from a 12-volt source in series with a transistor using no external resistance. Assuming that enough drive is available to the transistor, the selector magnets will get their required 60 mA current (at least under static conditions) and all seems well until trouble is encountered while receiving under difficult conditions.

An examination of the circuit constants will reveal the following: With a 260-volt, 60-mA loop, the circuit time constant is L/4330; with a 130-volt, 60-mA loop, the circuit time constant is L/2170; and with a 12-volt, 60-mA loop, the circuit time constant is L/200. This means the bias introduced by the loop time constant when using a 12-volt source is 11 times greater than with the 130-volt loop and 22 times greater than with the 260-volt loop! No wonder it is sometimes difficult to receive.

With a vacuum-tube magnet driver the situation is inherently better than with the "typical" transistor circuit because a higher voltage loop source is used. A triode or triode-connected beam power tube will give performance equal to metallic contacts for a given supply voltage. A pentode operated in a "constant-current" mode will outperform all other switching devices especially under the most difficult circumstance of several selectors in the same loop.

CONCLUSION

Selectors were made to be operated in loops having at least a 130-volt source. So long as the selector magnets are driven from a source of at least 130-V, loop time constants should not be a problem.

We have omitted from the discussion certain details such as selector operate and release currents and protection diodes used with transistor drivers. The topic will be discussed in a more thorough and detailed manner in Part 16, and it will include some items not covered this time.

Part 16 - MORE ABOUT TELEGRAPH LOOPS or THE CARE OF RTTY SIGNALS AND THE FEEDING OF SELECTOR MAGNETS

There is a common misconception about the method of driving the selector magnets in a teleprinter. Time constants and generally how they affect teleprinter operation were described in Part 15. Now, we will go into the subject in a detailed manner, describing some of the common loops and showing how each affects selector operation. The conclusion will give some simple rules for loop design or evaluation.

Probably the main reason that selectors are put into unsatisfactory loops is the close resemblance of selectors and ordinary-type relays. A run-of-the-mill relay has a coil voltage rating Therefore, it is logical to expect that the selector magnets in a teleprinter should also have some voltage rating and so long as that voltage is applied the teleprinter will function properly. ABSOLUTELY NOT!

Selector magnets have a current rating. They should be supplied from a current source, not a voltage source. Unfortunately a real, live current source is non-existent. However, a current source can be simulated by using a relatively high voltage in series with a resistance. (The higher the voltage source and resistance, the closer will be the simulation.) The following will show how to do this and what happens if it isn't done.

AN INDUCTANCE-FREE LOOP

In order to provide a point of reference, we will consider first a loop containing no energy-storage elements; i.e., no inductance or capacitance. Figure 1(a) shows such an idealized loop composed of some DC source, E, a resistor, R, and a switch, S. The voltage source and the resistor can be any value desired so long as their ratio permits a current, I equals E/R, of 60 mA to flow when the switch is closed. The switch can be metallic contacts, a vacuum tube, or a transistor. (Note that at this point we are not particular about the total loop resistance or supply voltage so long as the loop current is 60 mA. However, it will become apparent later that the source voltage and loop resistance are as important as the loop current.)

The switch is assumed to be driven in such a manner that it opens and closes at even intervals of 22 ms each, corresponding to the element length of a "60-Speed" RTTY signal.

BIAS DISTORTION

Bias distortion, or, as it is usually called, bias, is the measure of the unevenness in length of mark and space elements. Usually it is expressed as a percentage, and can be calculated from the formula: %Bias equals 100 (m - M) /M, where m is the actual length of a mark interval in units of time and M is the expected or normal length of a mark interval in the same time units.

For example, in Figure 1(b) the mark interval is supposed to be 22 ms long and it is shown as 22 ms long, therefore the percent bias in Figure 1 (b) is 100 (22-22)/22 equals 0%.

In all examples to follow, the "ideal" mark will be 22 ms long, therefore in all calculations M equals 22 ms.

RECEIVING DEVICES

In a receiving device such as the selector in a teleprinter, there are essentially two conditions or states that the device can be in, the unoperated or spacing condition and the operated or marking condition. When no current is flowing in the magnets, the armature will be unoperated or spacing. If current is slowly increased, the armature will operate when the current reaches a certain value called the operating current and at that point the armature will make a space-to-mark (S-M) transition, if the current is increased after the armature has operated, no further action will take place. If the current is slowly decreased, the armature will remain operated until a certain current value is reached, at which point the armature will release and a mark-to-space (M - S) transition will result. Once the armature has released, an additional decrease in current will cause no further action. The value of current at which the armature releases is called the release current.

The operate and release currents are dependent upon the immediate history of current within the device and upon the adjustment of the selector, especially the tension spring, if present, and the operated and non-operated air gap between the armature and the pole pieces of the magnets.

Because of the adjustment and history factors, the operate and release currents may be somewhat nebulous values. The operate current will always be more than the release current and may be several times as great. However, for illustrative purposes we will initially assume the two current values are equal and equal to 30 mA (half the normal loop current).

AN IDEAL SELECTOR IN A SIMPLE LOOP

Assume a selector could be built having no inductance in the magnets and having identical operate and release currents of 30 mA. Place this "ideal" selector in the loop shown in Figure 1(a). Because there is no inductance in the selector, the current would appear as shown in Figure 1 (b). The dotted line indicates the "operate-release" currents of this idealized selector. On a S-M transition in current, the selector operates when the current goes thru 30 mA as indicated by point A. On a current M-S transition, the selector re-

leases when the current goes through 30 mA as indicated by point B. (Point C will be considered later.)

Because the distance from point A to point B is 22 ms, the bias introduced into the selector is zero. (In this example m equals 22 ms, the distance from A to B.)

A SEMI-IDEAL SELECTOR

To progress one step toward a practical rather than ideal selector, assume the selector still has the same operate-release current levels of 30 mA, but that it has 4H inductance in the magnets. Insert this magnet into a simple series loop with contact protection as shown in Figure 2(a). Note that the supply is a 130-volt source. R is the total loop resistance including the selector magnet resistance. S is assumed to be metallic contacts.

The loop current is shown in Figure 2(b). Because of the magnet inductance, L, it it is no longer "square". In the S-M transition, the L/R time constant due to selector magnet inductance shows up and is approximately 1.84 ms. In the M-S transition, there is some overshoot resulting from the contact protection network composed of RCP and CCP. The time for the current to decay from 60 mA to the point where it makes the axis crossing is approximately 0.66 ms.

The operating point, A, is delayed by about 1.28 ms because of the delay in current build-up due to the L/R time constant. Due to the L-R-C "time constant", the release point, B, is delayed by approximately 0.20 ms. Therefore, bias is introduced into the selector as a result of its own magnet inductance. In order to calculate the bias, m must be determined; m equals 22.00 -1.28 plus 0.20 equals 20.92 ms. Therefore, the bias is 100 (20.92 - 22.0)/22.0 equals -4.9 or 4.9% spacing bias. This is not a bad value.

If a 260-volt source were used, R would be 4330 ohms and the bias would be approximately 2.1% spacing.

A "TRIODE" SWITCH

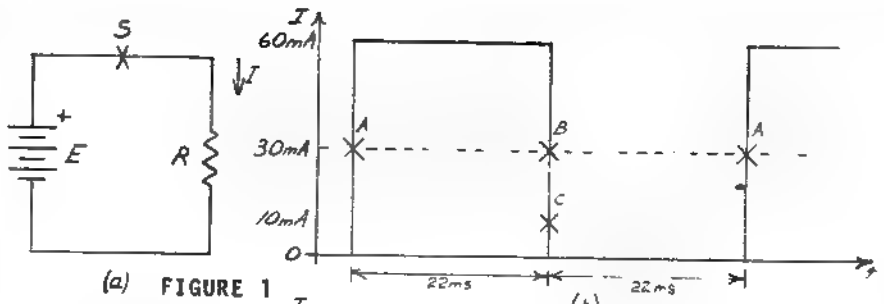
Metallic contacts may be considered archaic. Therefore, replace the contacts with a triode-like device such as a vacuum-pentode driven into hard conduction, a bipolar transistor driven into saturation, a unipolar transistor driven into the ohmic region, or a vacuum-triode. (It is tacitly assumed that the devices can be safely turned off rapidly.)

The only difference in current waveshapes between the "triode" and metallic contact circuits would be a vertical drop in current during the M-S transition because no C.P. network is used. The bias would be 5.8% and 2.9% spacing for the 130-volt and 260-volt loops, respectively.

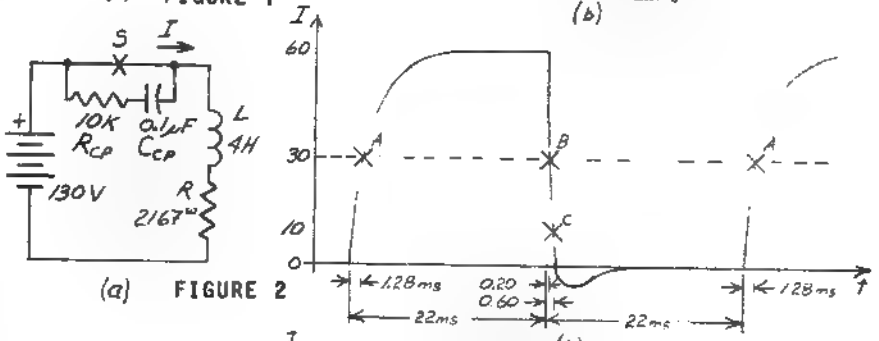
A "PENTODE" SWITCH

A pentode vacuum-tube operated in a "constant-current" mode as a selector magnet driver presents a complex situation that requires quite a bit of reasoning to fully explain. Therefore, we will only describe the requirements for best operation and the resulting waveshapes. (The term "pentode" is being used generically; it includes any device having a "pentode-like" characteristic. Bipolar and unipolar transistors when operated in a "constant-current" mode qualify but may not be practical because of their ratings.)

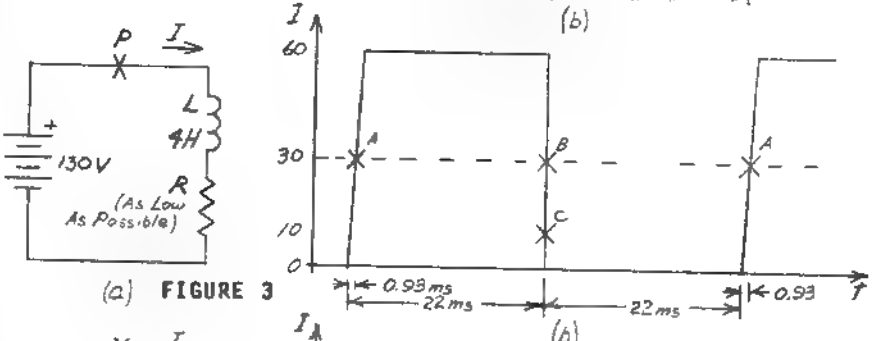
Consider the circuit shown in Figure 3(a). The "switch" marked P is a pen-



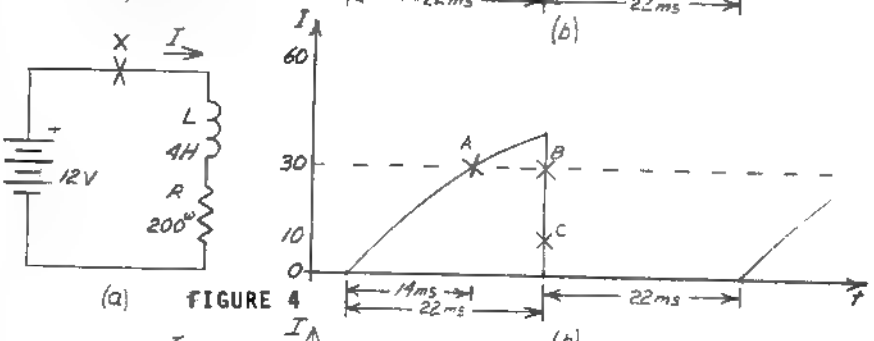
(a) (b) FIGURE 1



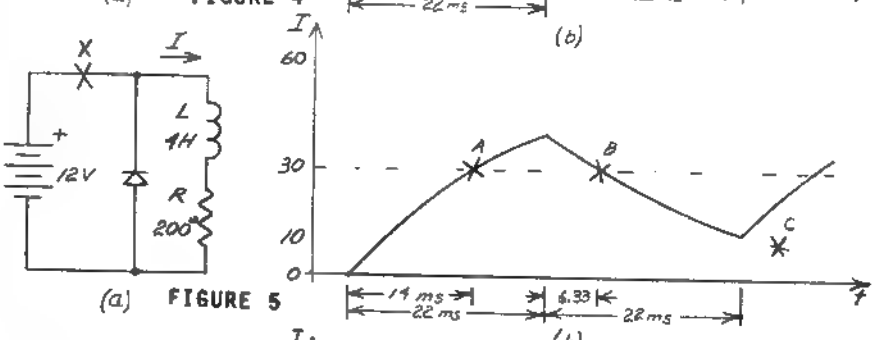
(a) (b) FIGURE 2



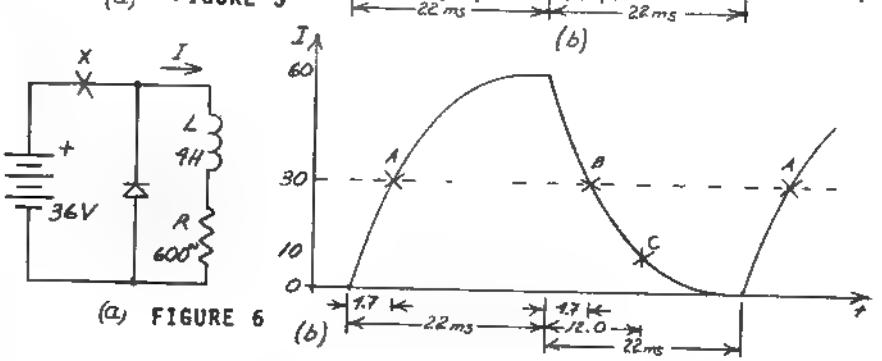
(a) (b) FIGURE 3



(a) (b) FIGURE 4



(a) (b) FIGURE 5



(a) (b) FIGURE 6

tode with the bias set to give 60 mA loop current during a steady mark. The resistance in the loop including the selector magnet resistance and excluding the DC plate resistance of the pentode should be as low as possible. It may appear that a low loop resistance is contrary to what has been said about time constants; however, in this case it is indeed desirable. An explanation of why it is true with pentodes and only pentodes is lengthy and will be omitted.

During the S–M transition, the current will rise linearly as shown in Figure 3(b). The rise time (the time to go from 0 to 60 mA) is dependent upon the supply voltage and the inductance, L, and not upon the loop resistance so long as the resistance is kept low. Note that the rise in current is linear rather than exponential as in all preceeding and all following examples. The rise time for a 130-volt source and L-4 H is 1.85 ms placing point A about 0.93 ms delayed, and for a 260 volt source the rise time is about 0.92 ms, delaying point A by 0.46 ms.

During the M-S transition, the resistance of the tube is nebulous, but is very high giving a very short time constant. Therefore point B will be undelayed. As a result, the bias will be 4.2% spacing and 2.1% spacing for the 130-volt and 260-volt cases, respectively.

LOW-VOLTAGE TRANSISTOR DRIVERS

Figure 4(a) shows a loop consisting of a 12-volt supply and a "switch", X, which represents the C–E "junction" of a bipolar transistor. In this circuit the total loop resistance, R, will probably be composed of only the winding resistance of the selector magnets. Because of parameter variation problems the transistor will probably have to be operated in the saturated mode. Therefore the transistor will act very much like a switch. If this is true, the loop current waveforms will appear as shown in Figure 4(b).

The time constant of the circuit, assuming 4 H inductance and 200 ohms resistance, will be about 20 ms. Therefore, even if the steady-state loop current is set to 60 mA, the current rises so slowly that it never reaches steady-state during a typical mark interval. However, if three marks are sent in succession, the current will reach 60 mA by the end of the third mark. This is intolerable, but if it is ignored, other problems will show up. (The situation in which steady-state current is not reached when rapid reversals are sent such as in the letter "R", but steady-state is reached during the letter "M", results in characteristic distortion, a most undesirable situation.)

The operating point, A, has been shifted approximately 14 ms. If the transistor can be safely turned off with no protection, the M–S transistion will be as shown, and the release point, B, will be in its normal position. Therefore, m equals 22 - 14-8 ms; the % Bias - 100 (8-22)/22- -63 or 63% spacing bias! This is also intolerable.

The inductive kick occurring when the transistor is turned off may damage the transistor. This can be prevented by placing a diode in the circuit as shown in Figure 5(a).

If we can assume that the diode when conducting has the same characteristics as the transistor when it is conducting, the waveshapes will appear as shown in Figure 5(b). Again, we have the problem of characteristic distortion resulting from the time constant being so long that steady-state is never reached when alternate marks and spaces are being sent, but steady-state is reached when several marks or spaces are sent in succession. For this example the bias is 35% spacing.

If the supply voltage is raised to say, 36 volts, the loop resistance would be 600 ohms and the time constant would decrease to 6.7 ms. This is shown in Figure 6. Point A and point B are shifted about 4.7 ms. each so that no bias is present and the time constant is sufficiently short to allow steady-state conditions to be established by the end of each unit. (This circuit appears to be satisfactory, but when an actual selector is considered, severe bias will exist.)

OPERATE AND RELEASE CURRENTS

As mentioned earlier, the selector operate current has to be higher than the release current and may be several times as great. To illustrate this consideration we will repeat the whole discussion (in abbreviated form, thank goodness!) Let us assume the operate current is 30 mA, and the release current is 10 mA. The point of operation, A, on all the diagrams will still apply, but the release point, B, will have to be replaced by point C.

In the simple contact-operated 130-volt DC loop shown in Figure 2(a), the shifting of the release point from B to C will slightly decrease the bias because point C is delayed by about 0.6 ms; the bias will be 3.1% spacing. Using a 260-volt source give 0.6% spacing bias.

When using the "constant-current" pentode with a practical selector, the bias will be the same as it was with the "semi-ideal" selector. 4.2% and 2.1% spacing. Although points B and C are at different current levels, they are in the same time position because of the vertical nature of the M-S transition. This has a very important consequence: If the M-S and S-M transitions in the current supplied to the selector magnets are nearly vertical, i.e., have very short time constants or rise times, the operate and release current values will not in themselves affect selector operation. As a corollary, when rise times are long, selector operation is very dependent upon the selector operate and release current values.

In the case of the 12-volt loop with a transistor and diode (Figure 5), the selector magnets will never release the armature! This phenomenon may manifest itself in a subtle manner. Assume a solid-state TU having this type output circuit is being tested. With a steady mark at the input the output loop current is 60 mA, with a steady space it is 0 mA. When characters are sent the printer will copy infrequent-transition characters such as T, M, and O but will be unable to cope with frequent-transition characters such as J, R, and Y.

The transistor and diode with a 36-volt source (Figure 6), although showing no bias previously, will now show A delayed by 4.7 ms and C delayed by 12.0 ms; this gives: m-22 - 4.7 plus 12 0 equal 29.3 ms. Therefore the bias is: 100 (29.3 -22)/22 equal plus 33.1 or 33.1% marking bias!

MULTIPLE SELECTOR MAGNETS

If more than one selector is inserted into the loop, as in the case where a page-printer and a reperforator are being operated simultaneously, the circuit analysis can be made with little additional effort. Essentially, in all the previous examples the time constants would be doubled; the bias would also double. This means that a circuit that is marginal with one selector in the loop (say 33% bias) will become inoperable with two in the circuit (66% bias). However, if the bias is only 1% initially, even four selectors will only result in 4% bias.

As selector magnets are added, the loop resistance will increase, lowering the loop current. The normal procedure for compensation is to employ a rheostat that is manually adjusted whenever a machine is added or removed. However, the change in loop current is smallest when the highest voltage source is employed. With a "constant-current" pentode no adjustment should be required.

HIGHER SPEEDS

The time constants of a loop are not dependent upon the speed of operation, but the length of a unit interval is. With higher speeds the length of a mark (and space) are shorter making the time constant a larger fraction of a unit. This has the effect of increasing the bias as the speed is increased.

MISCELLANEOUS

The voltage appearing across the selector magnets has been totally ignored, Its magnitude is useless except as an indirect indication of the steady-state loop current flowing in the magnets.

Traditionally, polar relays were used for many reasons; two reasons are: (1) The operate and release currents are nearly equal, and (2) The inductance of the relay winding is relatively low.

Because of these two characteristics, the relay will approach, closely, the "ideal" selector originally discussed, and as a result, will give better performance than a "barefoot" selector in a poor loop as well as not additionally "fouling up" the loop by adding a lot of inductance. This is why so many Model 15s come with a 255-A inside.

The selector within a Model 32 is driven from a solid-state unit built within the machine. When inserted into a loop it does not reflect the selector inductance back into the loop. The solid-state driver does for a Model 32 what the 255-A did for a Model 15.

CONCLUSION

The inductance of the selector magnets introduces time delays into a telegraph loop. These delays can affect operation to the point of total failure. The amount of delay is dependent upon the inductance of the selector magnets and the resistance of the loop. The larger the inductance, the greater the delays; the larger the resistance, the smaller the delays. Thus resistance can be used to offset the effect of inductance.

Because the loop resistance is directly proportional to the loop supply voltage, a good (but not infallible) figure-of-merit for telegraph loops is the DC supply voltage. The higher the supply voltage, the better the loop.

The actual effect of the time delays is dependent upon the operate and release currents of the selector; these values are dependent upon the design of the machine as well as the adjustment. However, the shorter the delay, the less the effect it will have upon the performance of the teleprinter regardless of the design and adjustment.

The best loop is one containing a 260-volt DC supply and a "constant-current" pentode. Second choice is a 260-volt DC loop containing metallic contacts or a triode. Any loop containing less than a 130 volt DC supply should be viewed with suspicion unless that "loop" was designed by the manufacturer of the teleprinter upon which it is used.

For those interested in experimentation, waveshapes similar to those described can be viewed on an oscilloscope. Use a good signal source; the best for this application is the I-193 Polar Relay Test Set because it supplies a continuous series of alternate marks and spaces at "60-speed." Place a low value non-inductive resistor in series with the loop at the ground end of the loop; place the oscilloscope across the resistor.

We would like to thank Doug Kerr, W2AIE, for many comments and suggestions.

PART 17

USING A MILLIAMMETER IN A LOOP

Frequently, questions are asked about why a dc milliammeter acts the way it does when placed into a telegraph loop. The following will (hopefully) explain its behavior.

A dc meter (voltmeter or millammeter) is an average-reading device. This means that the indication given by the meter is the average (with time) of the current flowing thru it.

If a very slowly alternating current is applied to a milliammeter, the meter will respond to the varying current and will, at any instant of time, give a reading corresponding to the current flowing at that instant of time, if a true alternating current were applied, half the time the meter would be going down scale because the current is reversed half the time and the deflection is directly proportional to the current flowing, including polarity.

The meter movement, although fairly lightweight, still has some mass and cannot, therefore, respond instantaneously. If the alternating current applied to the meter is increased in frequency, the meter may not be able to respond rapidly enough and the reading given by the meter will be less than it was previously even if the actual current being applied has the same magnitude. Remember, the higher the frequency, the faster the current (or voltage) varies with time.

If an even higher frequency alternating current is applied (60 Hz is sufficient with most dc meters), the meter time to respond becomes so slow relative to the rate of variation of the ac that the meter will read zero. In other words, by the time the meter starts to respond upscale, the applied ac has already reversed, and it is trying to make the meter read downscale, etc.

It is under the condition where the applied current is varying more rapidly than the meter can respond that the dc meter is truly average-reading. The average of a sine wave is zero, and that is what the dc meter reads so long as the meter "sluggishness" is sufficient to keep it from responding instantaneously.

A simple, but typical, telegraph loop is shown in Figure 1. The loop consists of a loop supply, some resistance, the selector magnets in the printer, the keyboard contacts, and a dc milliammeter. Assume for purposes of discussion that the dc milliammeter is 60 mA full scale. Also assume that the selector in the teleprinter is a 60 mA selector. Regardless of the loop supply voltage (which should be at least 130 V dc), the resistor is to be adjusted to give 60 mA loop current when the keyboard contacts are closed. (If the loop is keyed by a polar relay, a vacuum tube, or a transistor, the discussion is still exactly the same.)

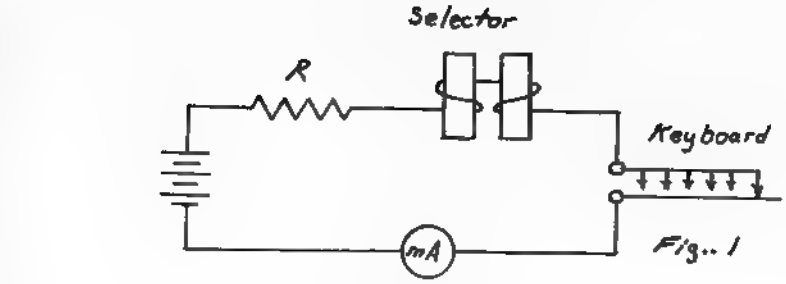


Fig. 1

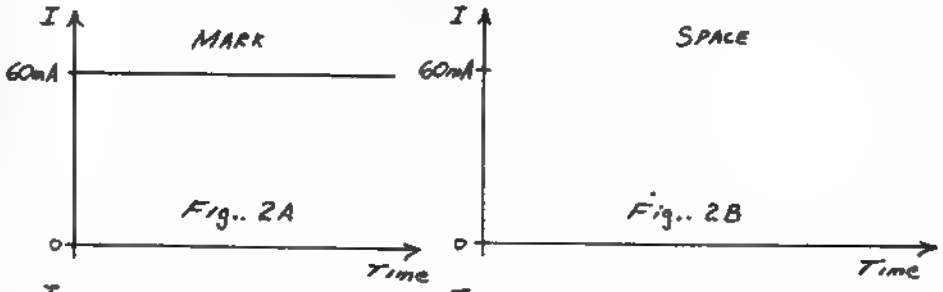


Fig. 2A

Fig. 2B

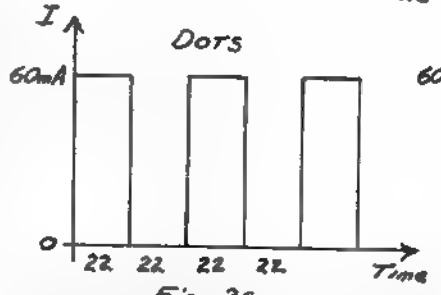


Fig. 2C

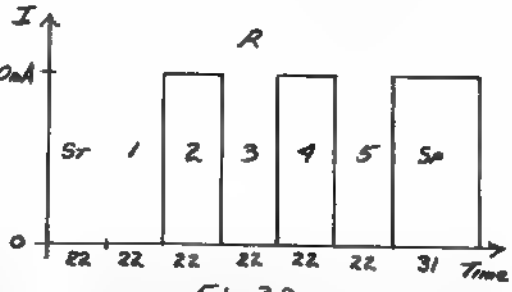


Fig. 2D

When the contacts are closed, the meter reads 60 mA. When the contacts are open, the meter reads zero. (Closed contacts correspond to a Mark, and open contacts correspond to a Space). Figure 2A shows current (I) versus time for a steady Mark, and Figure 2B for a steady Space. These pictures are as would be seen on a dc oscillosope.

What happens when a telegraph character is sent; i.e., when someone is "typing" something?

For initial explanation purposes, assume that the keyboard can send "dots." Dots are simply constantly repeated opens and closures of the loop in perfectly even intervals. Figure 2C shows how the loop current would vary when dots are sent (and there is no loop inductance). This is simply a square wave. During the first interval when the current is 60 mA, the meter will attempt to travel from zero toward 60 mA. However, if it is a typical meter, 22 milliseconds is not sufficient time for the meter to respond from zero to 60 mA. Therefore, it will only get part way up toward 60 mA when the loop current goes to zero. The meter will then try to return to zero. However, it was moving upward and will require a while to stop moving upward before it can start to move downward. It will probably be able to start moving downward but will not get to zero before the current goes to 60 mA again, and it again has to reverse and start going upward, etc.

Consequently, the meter will not read zero and will not read 60 mA, but will hover between the two values. If the meter is sufficiently sluggish (most meters are), it will appear to stand still somewhere between 60 mA and 0 mA. The question is: Where will it appear to remain stationary? Well, the meter is spending half its time trying to go to 60 mA and half its time trying to go to 0 mA. (Note, that when the dots are being sent, exactly half the time the current is 60 mA and exactly half the time the current is zero.) Therefore, the meter must indicate exactly half of 60 and 0, or 30 mA.

If the meter is less sluggish, it will not sit steadily at 30 mA but it will appear to hover or vibrate about 30 mA.

What happens when a single repeated RTTY character such as R is being sent thru the loop? Figure 2D shows the current as a function of time in the loop. As in the previous example, the meter will spend part of its time trying to get up to 60 mA and part of the time trying to go to zero. However, in this case the two portions of time are not equal. Because the meter indicates a simple average, the expected meter reading can be calculated as: (22x0 plus 22x0 plus 22x60 plus 22x0 plus 22x60 plus 22x0 plus 31x60)/163 equals 27.6 mA. Or: 75x60/163 equals 27.6 mA. Therefore, the meter should read 27.6 mA because this is the average.

In order for the meter to indicate the value just calculated, several conditions must be met: The steady Mark current must be exactly 60 mA, there is no inductance in the loop (inductance distorts the wave shape), the contacts on the keyboard are properly adjusted, the keyboard is being keyed at keyboard speed, and a Bell System machine with a 7.42-unit code is being used. These may seem to be unduly restricting, but that's life!

If any one of the above conditions is not met, the meter will not read exactly 27.6 mA. This can be used as a good indicator all components in the loop. However, if two (or more) of the above conditions are not met, the meter could read 27.6 mA. Therefore, the above is not an infallible check, but it is a simple, useful indicator.

When the repeated character, such as R is sent, the meter may appear to fluctuate more than with dots. The reason is that the start pulse and the first unit are both spaces; therefore, the meter has a longer time to move during this interval.

When just "typing" on the keyboard, the meter may appear to move somewhat erratically. This is to be expected, because the meter is constantly trying to find an average, and each character has a different average (or nearly so). Also, the time spent between characters is a variable depending upon the "typing" speed of the operator.

In summary, when a dc milliameter is used in a loop, it will indicate something other than 60 mA (Mark) and 0 mA (Space) when something is being sent in the loop. The meter cannot follow the rapid variations in loop current during the bit intervals within a character. When a steady repeated character such as dots or a letter are sent, most meters will indicate a steady current that is the average of the loop current. In the case of dots it will be 30 mA; for a repeated R, 27.6 mA; and for a repeated Y, 35.7 mA.

PART 18
SUMMARY

In the last 17 parts, we have been describing some of the fundamentals of RTTY. This has been done to give an overall picture of the various aspects of RTTY to someone who is new to the "art." We have now completed the opera, and will summarize what has been said.

THE TELEPRINTER

Printing telegraph machines communicate with each other (and within themselves) by means of a code commonly called the Baudot code. (Actually, it is not the Baudot code but the Murray code which is used by the common Teletype machines. For an extremely good discussion of the historical and present aspects of printing telegraphy see: "Principles of Telegraphy (Teletypewriter)" Navships 0967-255-0010, June 1967, SD catalog number: D219.8:T23; the price was $1.50. The code is composed of five even-length "pulses" or elements. Every character sent from a keyboard contains the five pulses. This is unlike the familiar hand-keyed "CW" code which contains many different length characters. The teleprinter requires that all characters be the same length because both the sending and receiving machines are mechanical things, and mechanical things are best suited for operation under repetitive conditions. (The same argument applies to the all-electronic keyboards and "printers," but the problem is not as severe with them.)

The code is generated by the keyboard. When a key is depressed, the machine translates the letter to be sent into the proper code combination corresponding to that letter and then sends the code. The receiving machine receives the code for a given character, then selects (or decodes) the character being received, and prints it. It should be noted that a complete teleprinter, although it may, from the outside, appear to be similar to a typewriter, is actually quite different inside. Basically, it consists of two completely separate and independent machines - a sending unit called the keyboard and a receiving unit called the printer. Usually the only thing common between the two units is the motor which drives both of them and the cover which is used to keep dirt and fingers out and the noise in. (Can't say it is very successful at any of those things!)

The "pulses" in the code used by teleprinters consist of an open circuit, called a Space, and a closed circuit, called a Mark. Because there are only 5 "pulses" per character, only 32 characters are possible. More than 32 characters are needed (just the 26 letters and 10 digits equal 36, and some punctuation is desirable, etc.). Therefore, most of the code combinations are used for two different characters; this explains why the keyboard is different from that of a typewriter. The dual use of characters is accomplished by shifting the machine into "Letters" or "Figures" position. Once a shift is accomplished, the receiving machine prints the characters corresponding to that shift position until a shift of the other type is received. (An exception to this is found in some machines which are equipped with an "unshift on space" arrangement whereby a shift to "Letters" occurs whenever a LTRS or a character space is received.)

Although only 5 elements are used in the teleprinter code to convey information, two other elements are needed. (Therefore, it is called a 7 or 7.42 unit code.) One of the additional elements is called a "Start pulse"; it is always a Space, and it precedes the first actual character code element. It was explained that the start pulse is needed to alert the receiving machine that a character is coming, and it is used to start the timing process within the receiving machine. The other extra element is called a "Stop pulse." It is always a Mark and it follows the last character code element; its purpose is to provide a period of time between the end of one character and the beginning of the next character so that the receiving machine can finish the decoding process and start the printing process before the next character arrives.

THE LOOP

A Teletype machine is made to communicate with itself or other machines by connecting the keyboard contacts and the selector magnets into a series circuit along with a variable resistor and a DC power supply of at least -130 volts. Essentially any number of machines can be connected into this series loop, although too many selectors will tend to distort the code pulses and may cause errors.Once the machines have been connected, the variable resistor is adjusted until 60 mA is flowing in the loop. The voltage across the selector magnets in any machine is irrelevant; the current flowing is what is important - however, the power supply in the loop must have at least 130 volts.

TRANSMITTING

The opening and closing of a loop by the keyboard can be transmitted by radio using two different, but closely related, methods.

In one method, called audio frequency shift keying (AFSK), the keyboard contacts are connected to an audio frequency oscillator; an oscillator built for this purpose is called an AFSK keyer. When the contacts are closed (Mark), the output frequency of the oscillator is 2125 Hz. When the contacts are open (Space), the frequency is 2295 or 2975 Hz (depending upon whether narrow or wide shift is being used, respectively). The output of this oscillator is connected to the audio (microphone) input of a voice (DSB AM or FM) transmitter. AFSK is usually used on 2 and 6 meters. AFSK when used with a DSB AM transmitter is called A2 modulation and when used with an FM transmitter is called F2 modulation.

The other method of transmission is called frequency shift keying (FSK).. The keyboard contacts are connected to the oscillator in a CW transmitter. The connection to the oscillator tuned circuit is made thru a diode and an RFC. (The actual circuit depends upon the specific make and model of the transmitter and upon the method of connection from the keyboard). When characters are sent, the contacts on the keyboard open and close and this changes the frequency of the transmitter. The frequency change is very small; usually, the Space frequency is either 170 or 850 Hz below the Mark frequency. Note that unlike CW, the transmitter is on the air continuously; the only difference between a Mark and a Space is a slight difference in the output frequency of the transmitter. FSK is usually used on 80 thru 10 meters. FSK is called F1 modulation.

FSK can also be generated by a hybrid of the two methods just described. The output of an AFSK keyer is fed into the audio input of an SSB transmitter. Because the transmitter suppresses one sideband and the carrier, the output signal appears identical to that of a directly generated FSK signal.

RECEIVING

When receiving an AFSK signal, the receiver is tuned as it would be for a voice signal. The output from the receiver is connected to the input of a terminal unit (TU). The output of the TU is connected into a loop containing the selector magnets of a teleprinter. The TU "listens" to the tones. When a Mark tone is received, the TU allows current to flow in the loop; when a Space tone is received, the TU stops current flow in the loop.

FSK is usually received in a manner similar to CW. The BFO in the receiver is turned on and the FSK is automatically converted to AFSK by the receiver. The receiver tuning is more critical than it is with CW because the receiver tuning determines the frequencies of the AFSK signal appearing in the output, and the frequencies must correspond with the frequencies for which the TU is built. Once the receiver has converted the FSK signal to AFSK, the remainder of the receiving process is the same as it is with AFSK.

AN OVERALL VIEW

The whole sending and receiving process can be summarized by saying that when the keyboard contacts are closed, the transmitter sends out the Mark frequency; the receiver output will be a Mark tone and the TU will close the receiving loop. When the keyboard contacts are open, the transmitter sends out a Space frequency, the receiver output will be a Space tone, and the TU opens the receiving loop.

*****

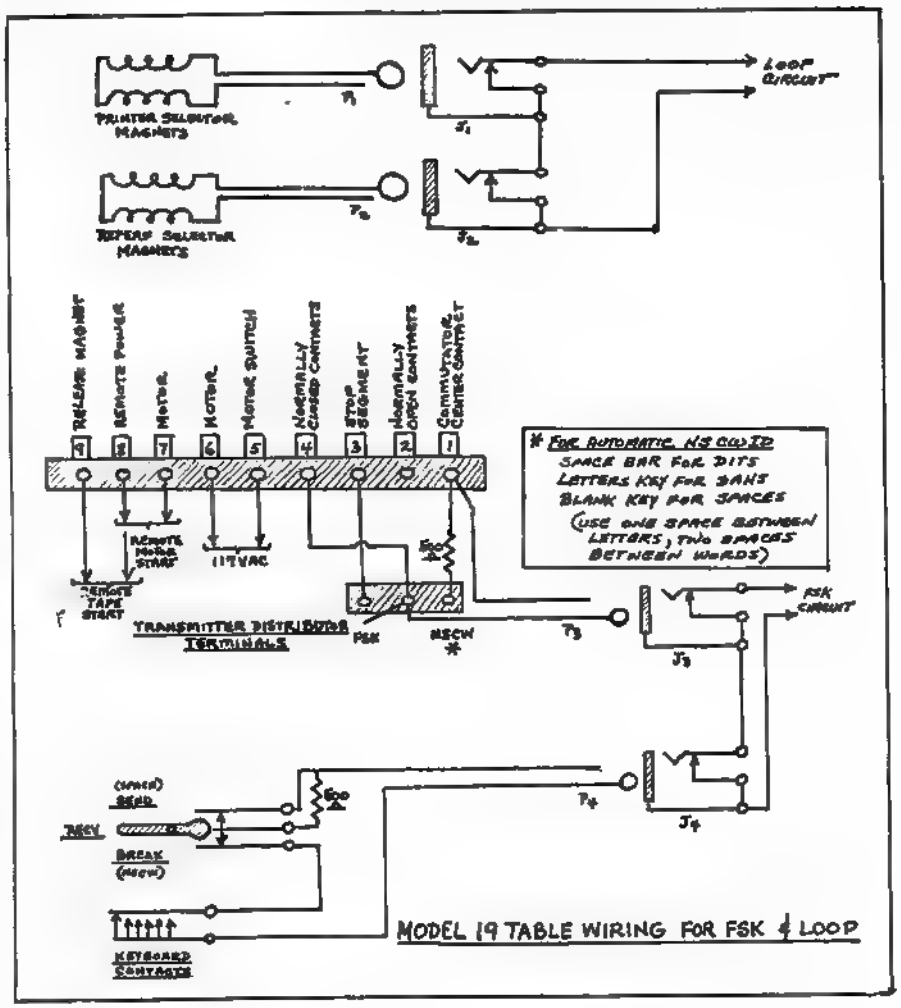
SIMPLE WIRING FOR THE MODEL 15-19 TELETYPE

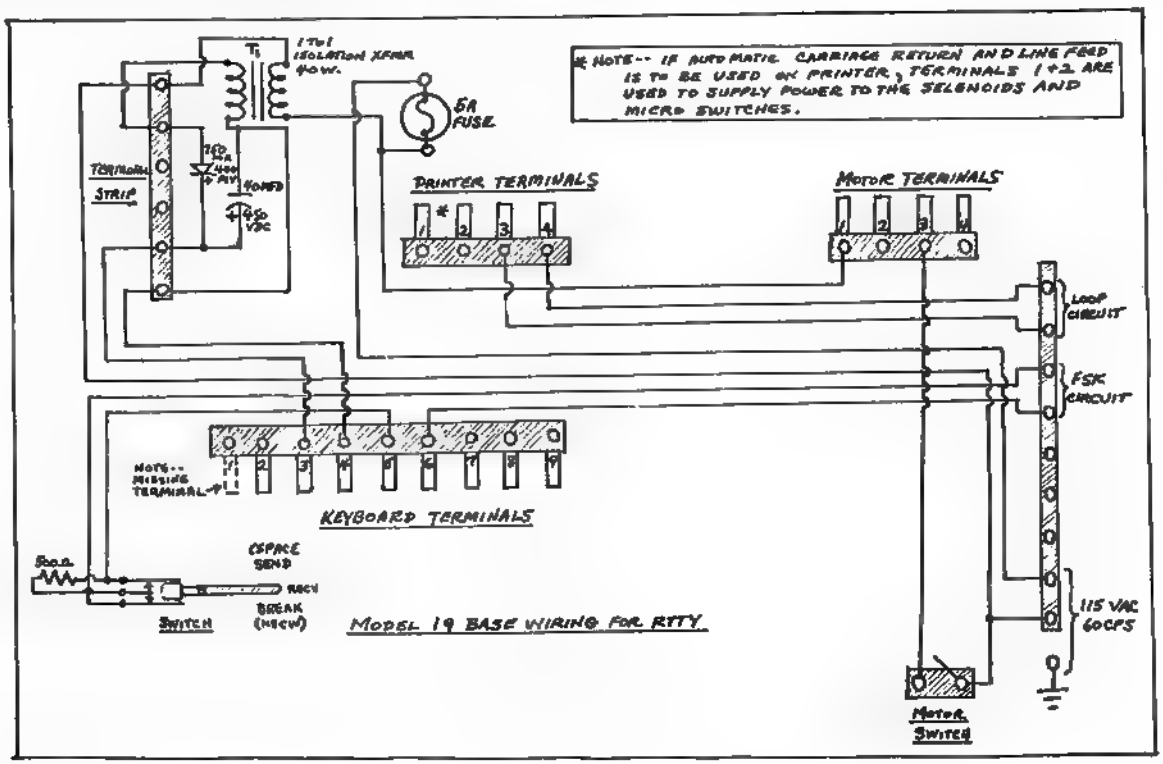
EVERETT HAWLEY, K8JTT
790 South Oxford Rd.
GROSSE POINTE WOODS, MI 48236

Most nineteens contain excessive wiring and components such as switches, filters, line resistors, relays, brackets, terminals, nuts and bolts, etc. Far more than is required or even desirable for good amateur RTTY. When the average ham takes a first look at his machine and tries to compare it with the diagrams of teletype corporation, which is about all that is shown in the various handbooks, it is no wonder that he is completely lost. But actually the wiring needed for best amateur operations is extremely simple. So why not get out the cutter, hex wrenches and screw driver and strip the machine down to its basic mechanical parts. This will also give you a chance to clean up all that oil and grime that covers everything on the base, motor, keyboard and TD. It is rarely necessary to strip the printer section so that can be merely cleaned up with rags, swabs, a tooth brush, small wire brush, Q Tips, or anything handy. Just get the excessive oil out of there.

The enclosed charts provide for the simplified rewiring and furnish a basis for later changes and trouble shooting that will be worth far more than the one evening that it should take to get the job done. As far as practicable these charts are oriented to the general location of terminals and other components as viewed from the top and front of the base and keyboard. You will note that provision has been made for certain remote functions that can be added now or later with little difficulty.

The narrow shift CW provision will




* NOTE-- IF AUTOMATIC CARRIAGE RETURN AND LINE FEED IS TO BE USED ON PRINTER, TERMINALS 1 & 2 ARE USED TO SUPPLY POWER TO THE SELENOIDS AND MICRO SWITCHES.
T1 1 to 1 ISOLATION XFMR 40 W.
5A FUSE
TERMINAL STRIP
PRINTER TERMINALS
MOTOR TERMINALS
LOOP CIRCUIT
FSK CIRCUIT
NOTE-- MISSING TERMINAL
KEYBOARD TERMINALS
500Ω
(SPACE) SEND
MAKE
BREAK (MSCW)
SWITCH
MODEL 19 BASE WIRING FOR RTTY
115 VAC 60CPS
MOTOR SWITCH

operate only if the FSK or AFSK line runs directly through the keyboard and TD. But the automatic CW from tape can also be made to operate for wide shift or mark or space make or break. Also note that the send-receive-break tab sticking out of the left front of your machine cover makes a swell little CW ID key if the latching arm is removed. Ours is wired to give narrow shift CW by keying it and to give space when raised up by breaking the FSK line for testing.

If you follow the charts for the power supplies, no outboard supplies will be required, which will leave the back of your table clear for just wiring and terminals. Note punch and TD magnet supplies are merely simple diode circuits from the AC line.

If you have a model 15 instead of the 19 the same diagrams will apply. Just omit any wiring going to the punch or TD.

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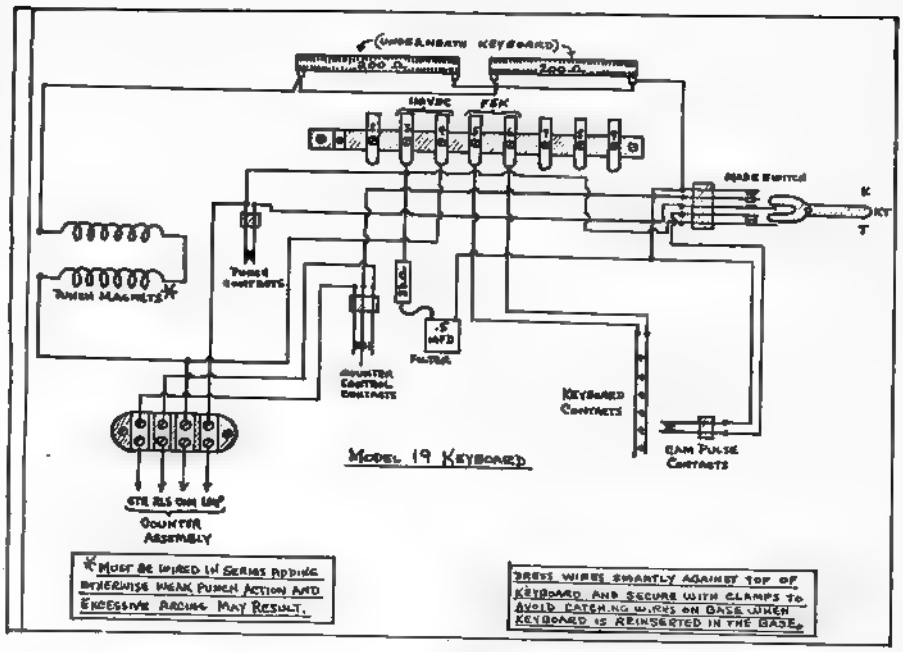
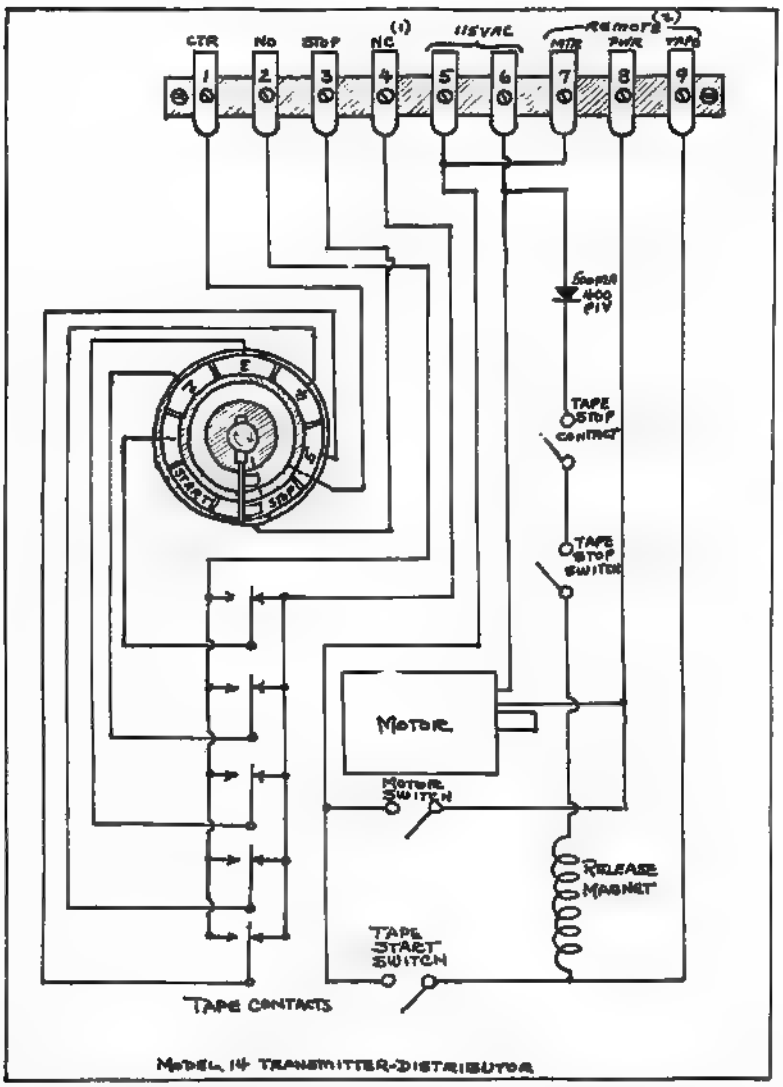

MODEL 19 KEYBOARD
COUNTER ASSEMBLY
KEYBOARD CONTACTS
CAM PULSE CONTACTS
* MUST BE WIRED IN SERIES ADDING OTHERWISE WEAK PUNCH ACTION AND EXCESSIVE ARCING MAY RESULT.
DRESS WIRES SMARTLY AGAINST TOP OF KEYBOARD AND SECURE WITH CLAMPS TO AVOID CATCHING WIRES ON CASE WHEN KEYBOARD IS REINSERTED IN THE CASE.



(1) NOTE- NORMALLY CLOSED CONTACTS ARE THOSE IN CONTACT WHEN DISTRIBUTOR BRUSHES ARE ON SEGMENTS 1 THRU 5 (NOT STOP OR START) WITHOUT TAPE IN GATE.
(2) NOTE- TERMINALS 7,8 & 9 ARE FOR REMOTE CONTROL OF MOTOR AND TAPE START FUNCTIONS.

MODEL 15 PRINTER

The model 15 is a page printer, self contained, with keyboard and motor. It has a single magnet selector, which can be operated direct from your Terminal Unit or through use of a polar relay. Two types of selectors are to be found on various models of the 15, first the so called "pull type", magnet which requires the current to be on to pull the selector back after each operation. The second type is called a "Holding Type" selector, which mechanically returns the selector to operating condition after each operation. The later machines have the second type of selector, but does in no manner make the earlier version unsatisfactory. Both types can be operated with the two coils either in series or parallel, to provide 30 to 60 mil operation.

The keyboard has the standard type of distribution assembly, which is similar to that in the model 12, 14, 19, 24, 26 machines. As received, they have the coil and condenser across the contacts which has to be removed for operations of your FSK direct. However, if a polar relay is used, it can be left in place to reduce RF noise generated by the contacts breaking the keying current.

In the model 15, the paper is held on a roller which does not move back and forth as in the model 24 and 26s. The type basket travel from left to right a copy is received.

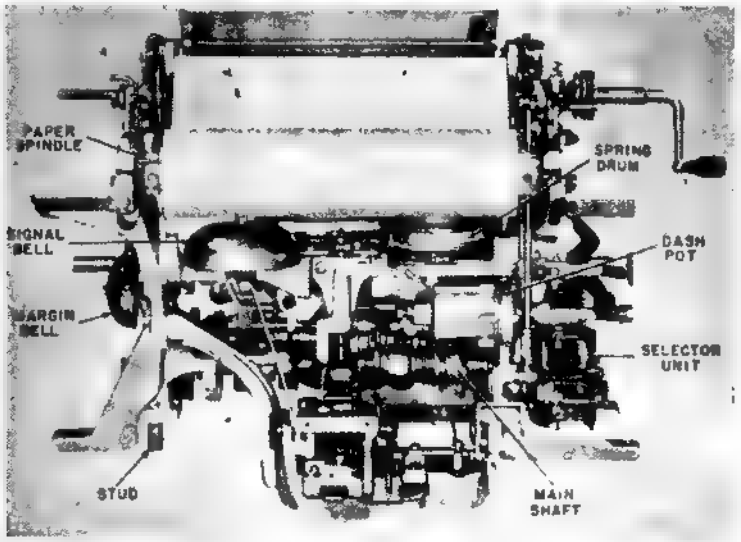
The range finder is located on the left hand side of the printer, and can be adjusted when necessary through a small door on the left side of the cover.

An "unshift on space", cut out or in, lever is provided under the front of the printer. See photo for location of this feature. Man DX RTTYers will find this feature to be of advantage in copying weak signals, especially when a static pulse operates the shift to upper case. It can be cut out by shifting the lever to the other position.

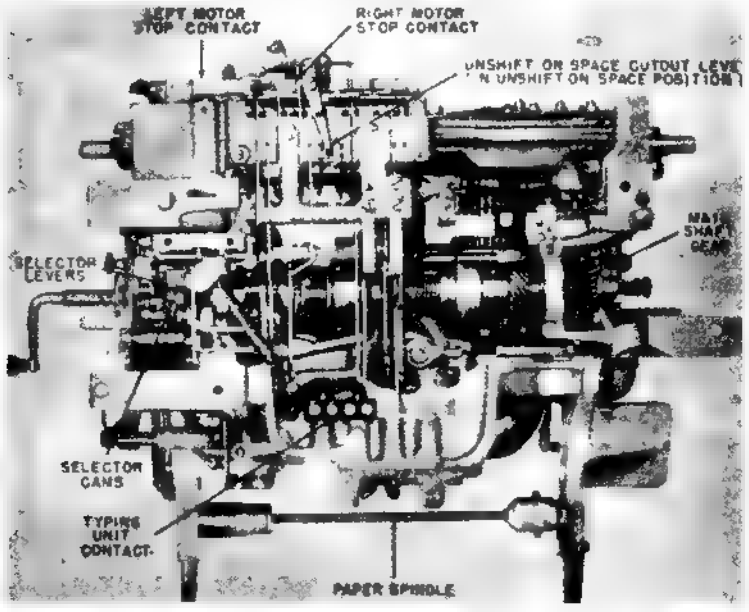
Also the keyboard can be replaced with a 15 perforating keyboard, which

makes the 15 similar to a 19 unit. This requires a power supply which will provide 500 mils at 110 volts DC. The base casting is slotted for this modification.

The complete model 15 is made up of the following major parts: Base, with wiring, keyboard which plugs into the base; motor with electrical connections which make, when the motor is bolted to the base; printer, which contains all of the selecting and printing functions; a cover which completes the unit. Additionally some of the 15s have a polar relay-socket mounted in the rear, others have an additional relay which controls the motor from line current. Other type motors can be had to operate from generator AC supplies or DC. Other type faces can be purchased to convert to weather operations. To mount the type faces soft solder is used, which permits one change the fractions pallets quite easily. Key tops can be changed by lifting at the top of the keys and pulling up, to replace, reverse the operation. Normal amateur operations are at a speed of 60 WPM, using gears which have numbers 74912 and 74913. However, speeds of 75 WPM can be had for other uses.



Back of typing unit.

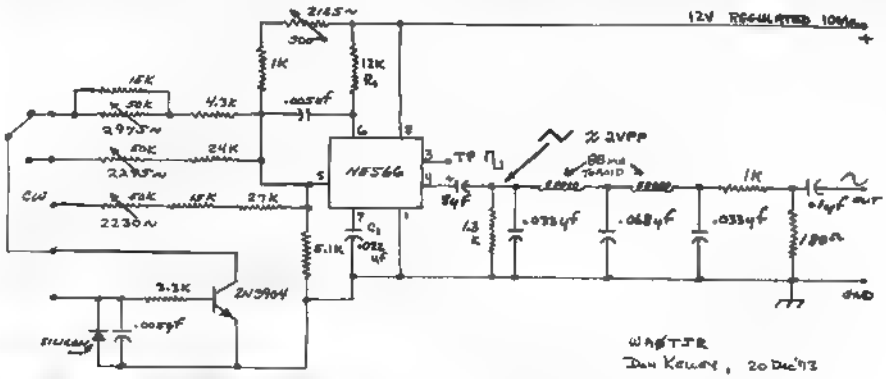


Bottom of typing unit

MODERN AFSK OSCILATOR

DONALD KELLY, WA@TJR
1490 Yaqui Dr.
FLORISSANT, MO. 63031

My quest for a simple reliable and inexpensive AFSK was solved by the discovery of the Signetics function generator -- the NE 566. The first use of this integrated circuit as an AFSK was detailed by K7ZOF in Ham Radio of March '73. After reading his article and the Signetics application notes, I decided to design my own with the circuit results shown.



This unit costs about $10 to build. It produces stable sine wave outputs for the purest, but the filter can be removed if a triangle modulation waveshape is acceptable. Total current consumption is 10 Ma at 12 volts. The total part count is 29 versus 54 in the AK-1. The reliability of the unit has been fine. After a months useage (I leave my transistor gear on 24 hours a day 7 days a week) there was no shift in frequency.

The NE566 is a voltage controlled oscillator. The basic frequency is set by R1 and C1 and then modulated (FSK'd) by shifting the voltage on pin 5. A well regulated source of voltage is essential. One of the three terminal regulator IC's will handle both the TU and the AFSK.

The parts are those in my junk-box. None are critical. The filter needs 1.2K terminations and there is no difference between mark and space tone amplitudes at the output. The resistance ratio was chosen to match the output of my Heath mike. All resistors are 1/2 watt carbons since they carry nill current. The pots are single turn cheapies and you can hit the frequencies on the nose with the values shown. The 2N3904 needs plus 12 on space and plus 2 or so on mark.

****

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NS-1 PLL DEMODULATOR

NAT STINNETTE, W4AYV
PO Box 1043
TAVARES, FL. 32778

Here's a terminal unit which should interest both the beginner and old timer. It is easy to assemble and adjust and does a good job of copying both wide and narrow shifts. The circuit is shown in Fig. 1. It uses a 741 IC as limiter, an NE565 phase lock loop IC, another 741 IC as voltage comparator or "slicer" and an MJE340 or 2N5655 keying transistor.

The TU has no filters as it works on the FM principal. The theory of operation of the phase lock loop has been covered extensively elsewhere but a general understanding will be helpful. Simply stated, the incoming signal locks on a voltage controlled oscillator in the IC. The frequency of the oscillator is placed between the frequencies of the mark/space tones. As these tones alternate, the output of the PLL can be made to produce a plus and minus voltage by connecting a voltage comparator to it. This plus and minus voltage corresponds directly to the mark/space tones and can be used to key the loop circuit of the teletype machine.

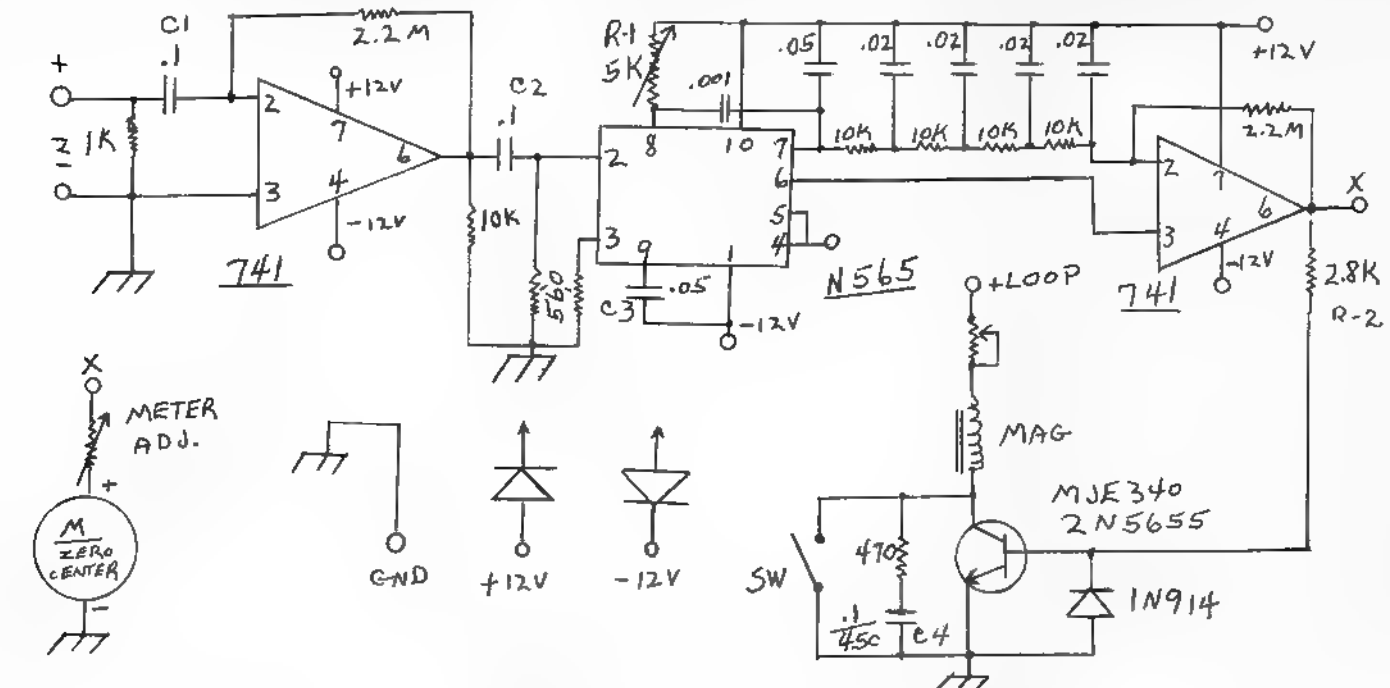
Construction requires no particular care and a perf. board serves quite well. A regulated power supply of 10-12 v.d.c. plus and minus is required. Sockets should be used for the ICs. The transistor has three pins in line and connection can be soldered directly to them If a printed circuit board is used, molex pins can be used for the ICs as they are cheaper. (1).

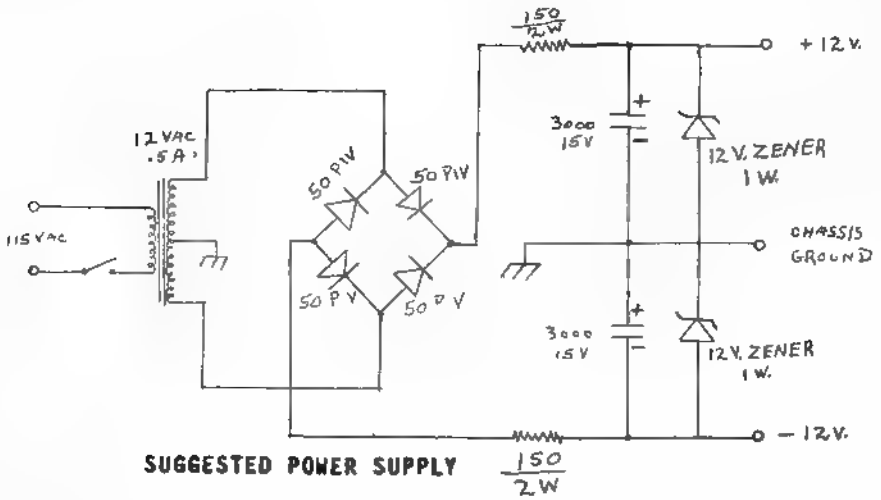
C1, C2, C3, C4 are dipped mylar-paper. They should be 100 V. or less for small size. C4 is 400 V. Others are disc ceramics. Resistors are 1/2 watt carbon. R-1 5K pot. can be a small mini-pot. with wire leads. Use a heat sink when soldering the 1N914 diode. The diodes at plus and minus input voltages are for safety to avoid accidental reversal of voltages. They can be any small silicon rectifier diodes 50v., 100 ma. Use a low heat soldering iron about 25 watts. Do not use a gun.

A tuning meter is required and the simplest is a zero center milliameter or microameter with suitable dropping resistor. The value of this dropping resistor depends on what size zero center meter is used. A safe way to determine the value is to start out with a 200 K pot. adjusted for full resistance and gradually reduce the resistance until you get a full scale reading on the plus side when the mark/hold tone is received. Then you can measure the resistance you have in the pot. and substitute a fixed resistor. (1/2 watt is ok).

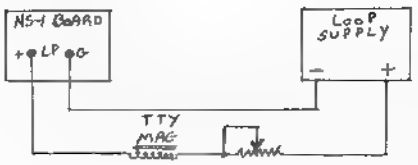
The meter is connected as shown in the diagram. It indicates a plus current on mark/hold and a minus current on space. When receiving a properly tuned FSK signal the needle tends to hover around zero center. If no zero center meter is available, use a VTVM set at about 25 v.d.c. and advance the needly to center scale.

Adjustment is easy. Connect the loop power supply as shown in the diagram. This is usually 120 v.d.c. with a resistor in series for adjustment of proper loop current usually 60 MA. Consult the specifications for your particular ma-





SUGGESTED POWER SUPPLY



BLOCK DIAGRAM-NS-1 - LOOP SUPPLY & PRINTER

NS-1 PLL DEMODULATOR
Nat Stinnette Electronics
P. O. Box 1043
Tavares, Fla. 32778

chine. A 0-100 MA meter is often kept in the loop circuit to monitor the current. Next, connect the 10-12-v.d.c. regulated power supply to the TU. Check the plus and minus voltages. These should be within .5 v. of each other. Input can be 500 ohms or even the speaker output of the receiver which works quite well. Close SW-1, tune in a good steady narrow shift RTTY signal preferably running a tape. The received tones should be in the vicinity of 1500 Hz so 2 kHz selectivity on the receiver can be used. This is not critical and can be done by ear. Set R-1 at the end of rotation which is maximum resistance. The zero center meter should read approximately zero or a little on the plus side. Now advance R-1. The meter should move to the plus side and flicker back toward zero. If it moves to the minus side and flickers back toward zero you are receiving upward shift. To correct this, change to the other sideband if receiving in the SSB mode or move the BFO to the other side if receiving in the CW mode. You will then have to retune and start the procedure again. Remember, the meter should be on the plus side when the mark/hold tone is received.

Next, open SW-1 and turn on the teletype machine. As R-1 is further advanced a point will be reached where the machine will begin to print and the needle of the meter will stay pretty near zero during copy and maximum plus on mark/hold tone. This is the spot where R-1 should be set. As R-1 is advanced still more the needle will go back toward the minus side and eventually the machine will run open. With a little practice in tuning and watching the meter a signal can be tuned in with no trouble at all. After a while you may want to change R-1 slightly one way or the other to receive signals better at some different tones. But once it is set properly it need never be changed.

There are no provisions for using a scope for tuning the usual cross pattern. This method requires tuned filters for some specific cross pattern. This method requires tuned filters for some specific audio frequencies. If you have a scope which will receive a cross pattern of a RTTY signal, hook it ahead of the NS-1, or at the output of your receiver which feeds the NS-1. Tune in a signal and get the proper cross pattern and then set R-1 to receive good copy. This way you will have a scope tuning indicator for use with the NS-1.

It is possible to receive both wide and narrow shifts with one setting of R-1 but if it is set to receive narrow shift, the wide shift is sometimes hard to tune. However, since narrow shift is generally used now, one setting for it should suffice. If you expect to receive both shifts regularly it would be well to install a second pot. with a switch to select either wide or narrow shift.

The NS-1 was developed primarily for FSK using the low tones to take advantage of a narrow passband in the receiver. It will copy AFSK if the shift is downward, that is mark/hold tone high, space tone low. It will not copy AFSK if the shift is upward (mark/hold low, space high). To receive AFSK if shift is upward as used on VHF bands, a simple change in the circuit will permit this. Reverse the leads going to pins 2 and 3 of the second 741 IC Leave the 2.2M resistor connected to pins 2 and 6. It may or may not be necessary to change the value of resistor R-2 to around 15K. In some cases, the larger value is necessary to completely cut off the loop current on space.

Pins 4 and 5 of the NE565 are tied together. Headphones connected at this point and ground will permit you to hear the VCO. This may be helpful in trouble shooting. No signal or a rough unstable signal would indicate a defective or incorrectly wired NE565.

Always close SW-1 when transmitting. Also, it will probably be necessary to close it when tuning as random noises will produce garble on the machine.

During operation the NE565 will be quite warm to the touch as will the transistor. This is normal.

(1) Note - Printed circuit boards, undrilled, as well as complete units are available from the author. Write him for information and prices.

****

ST-5 DEMODULATOR

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12130 Foothill Lane
LOS ALTOS HILLS, CA. 94022

Many newcomers to rtty have complained that a current yet simple demodulator hasn't been published for them to build. The W2PAT unit in the ARRL handbook is nearly 15 years old.

THE ST-5 DEMODULATOR

While developing a unit based primarily on ICs to replace the TT/L-2, a very simple modulator with great potential was developed: the ST-5. As with any simple circuit, the cost of the power supply is out of proportion with the rest of the unit. At 1970 prices the ST-5 costs only $14.50 less loop supply ($8) and a plus-minus 12-volt supply ($11).

The total cost of $33 is not overly impressive until you realize this unit can, if desired, be used as a building block for the more exotic ST-6. Almost every component used here can be used in that unit. The ST-5 is a basis from which the beginner can expand - it's not just a collection of parts that will find no further use when he is ready to broaden his horizons to more sophisticated equipment.

FEATURES

The ST-5 uses two operational amplifiers (fig. 1). One is an audio limiter, and the other is a trigger stage to drive the keyer. It has a 175-volt loop supply of the same type used in the TT/L, which provides plus-minus voltages for keying a transmitter and also features narrow-shift cw identification. Finally, the ST-5 has a symmetrical plus-minus 12-volt power supply.

LIMITER

The 709C op amp has over 90-dB gain and is good to over 10 MHz. It makes an ideal limiter. The zener diodes on the input don't assist in the limiting, they merely protect the 709C against damage in the event of excessive audio input (hardly likely but worth the protection). The limiter puts out square waves and is so powerful it starts working on input signals as low as 200 V. The 25k pot merely balances the small offset input voltage for maximum gain. This voltage varies slightly from one unit to another, so a control pot was added rather than a fixed resistor, which many units use.

DISCRIMINATOR/DETECTOR

It's difficult to use the same value inductor with different capacitors and expect to obtain two similar filters of equal characteristics. To get similar band-width, voltage output, noise response, etc., some loading is necessary. Most simple demodulators merely balance the voltage or ignore all the problems completely. Without belaboring the point, it's not a simple job to get all these factors to balance suitably; but it is possible, and the Mainline units all have filters that have been designed with care.

The ST-5 offers a choice of the 2125-2975 mark and space tones (considered standard), or the 1275-2125 low tones necessary in some modern receivers. (Actually nearly all these receivers respond beautifully to 2975 tones and higher, but a new bfo crystal is needed.) The best results come from the 2125-2975 tones, since the two frequencies are only about 28% apart while the 1275-2125 tones are 40% apart. thus it's a more difficult job to separate the harmonics and achieve proper filter design.

The detector features full-wave rectification for most efficient filtering of the dc ripple remaining after the audio has been rectified. A simple RC low-pass filter removes the remaining audio component.

SLICER

The slicer takes the small voltages from the filters and changes them to roughly +10 volts for mark and -10 volts for space, regardless of the original amplitude. This in reality is a dc limiter, as a signal as small as a 100 μV or so will cause the unit to saturate completely, either plus or minus, depending upon the polarity of the applied signal voltage. The unit has so much gain that at the cross-over point, a change at the audio input as small as one or two Hz will cause this trigger stage to flip from +10 to -10 volts. This is another way of saying shifts as low as 3-4 Hz could be copied on the ST-5 if tuned in properly.

KEYER STAGE

A 250-volt Motorola 20W transistor selling for $1.06 is used. The normal loop-supply current for tty machines is 60 mA. This transistor has a large amplification factor and acts like an on-off switch. When on, the power consumed in the transistor is only 0.012 W; so in the ST-5 there's no way you could ever damage that transistor.

An RC network in the 2N5655 collector takes care of the back emf developed by the inductance of the selector magnets in the printer during the transition from space to mark. The transistor is biased off during space. A diode in the base circuit keeps this negative voltage below the point at which the base-emitter junction would be reverse-biased.

STANDBY SWITCH

When S1 is closed, the unit is placed in mark. When S1 is opened, the printer can follow whatever is fed into the limiter from the receiver.

As explained previously, the unit has so much gain that a signal as small as 3-4 Hz can be copied if tuned correctly; this is called straddle tuning. However, for 170-Hz shift you may wish to add a switch that changes the space filter to the new frequency. **Fig. 2** shows the way this would be accomplished if using the normal 2125-2975 tones, and **fig. 3** shows the circuit for the low tones of 1275-2125. This is merely an expedient and doesn't result in proper filter balance, but it provides good 170-shift reception with the switch closed, or normal 850-shift reception with it open.

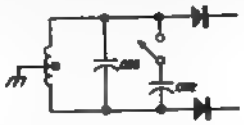


fig. 2. Switching circuit for adding 170 shift to space filter for 2125-2975 tones.

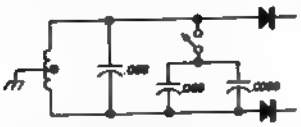


fig. 3. Switching circuit for adding 170 shift to space filter for 1275-2125 tones.

TUNING INDICATOR

Provisions are provided for connections to the vertical and horizontal amplifiers of a scope (**fig.1**). It is customary to connect the mark signal to the horizontal amplifier and space signal to the vertical amplifier, although many reverse this method.

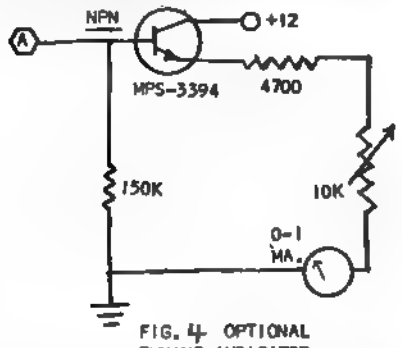


FIG. 4 OPTIONAL TUNING INDICATOR

Most people prefer a scope indication, but an excellent tuning indicator is provided at point A (**fig. 1**). A voltmeter connected to this point will give equal voltage indication for mark or space. With rtty signals the meter should stand still. If it doesn't, retune the receiver until it does. If straddle tuning a signal, the meter may read less than normal, although it won't move. This is normal and merely indicates the shift being copied is not the correct shift for the filters you're using.

Fig. 4 also shows how a 0-1 mA meter may be added. An inexpensive npn transistor is used, such as the MPS-3394, although any npn transistor would be satisfactory here. The capacitor merely dampens the meter so it doesn't flip around too violently. If your meter is too damped, remove the capacitor or try a smaller value. This was suitable for the inexpensive imported meter used in my unit.

THE TRANSMITTER KEYER

Fig. 5 shows a typical fsk keyer for installation in the transmitter. The components can be mounted on a small terminal strip and placed near the vfo tube under a convenient mounting screw which also serves as a ground return. The trimmer is connected to the cathode of the vfo tube and the tube replaced in its socket; thus, no changes of any type are made to the transmitter and its resale value is not affected. There should be room for several keyers if you wish to have the convenience of both 170 and 850 shift.

Although a 3-12 pF trimmer is shown in **fig. 5**, some transmitters only require a 1.5-7 pF trimmer. It is suggested that you do not substitute for the 1N270 diode as it is superior to most other types in this application.

If your signal is reported as "upside down," reverse the 1N270 diode. If you do not obtain sufficient cw shift with this connection (conduct on mark), the 500-ohm cw-shift pot should be connected to the opposite side of the 8.2k resistor at the junction of the two 15k resistors (**fig. 1**).

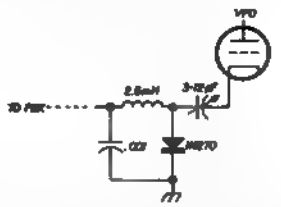


fig. 5. To add fsk to literally any transmitter, connect a 3-12 pF trimmer to the cathode pin of the vfo tube.

COMPONENTS

The 709C op amps are supplied by various manufacturers including Signetics, Fairchild, and Motorola. Prices are constantly being reduced as devices become available from more companies. When I first started working on a super deluxe demodulator in the fall of 1967, I paid over $10 each. Now they're too cheap not to use. The Motorola unit can be purchased through most distributors, including Allied and Newark. The Fairchild unit can be mailordered from the firms below. Specify the T0-5 can, as this is easier to work with than the dual in-line 14-pin type (same cost).

The diodes marked G in **fig. 1** are 1N270 germanium at 32¢ each. Those marked SIL are most any silicon type, such as the 1N2069. The one in the loop supply should, however, be a minimum of 400 volts PIV. Fifty-volt PIV is suitable everywhere else.

The 88-mH toroids are available from various sources for about 40¢ each. They're wired in series for 88 mH, and the junction of the two windings is grounded.

If you have an accurate means of determining the frequency, you can tune the filters by removing turns of wire from each of the two sections concurrently to keep the turns ratio in the two windings the same. One turn from each of the two windings will increase the frequency about 6 Hz at the 2125 frequency, for example.

Use Mylar capacitors, such as the Sprague Orange Drop. Twenty-five-volt capacitors are adequate, but you'll probably wind up getting 200V types. They are only 15-21¢ each.

The pots can be the inexpensive 39¢ Mallory PC board MTC types. Other power transformers may be used, but the Triad F-40X is an excellent buy.

PRINTED-CIRCUIT BOARD

The printed-circuit boards shown in the ST-5 in the photographs hold all of the components except the two transformers and the control switches. This greatly enhances construction, and at the same time makes it possible for nearly anybody to build an extremely nice-looking unit. The printed-circuit board includes one section for the power supply and another for everything else. The board may be split down the middle and the two sections mounted back-to-back as I did in my unit, or the board may be left intact and used with a more shallow chassis.*

ADJUSTMENT

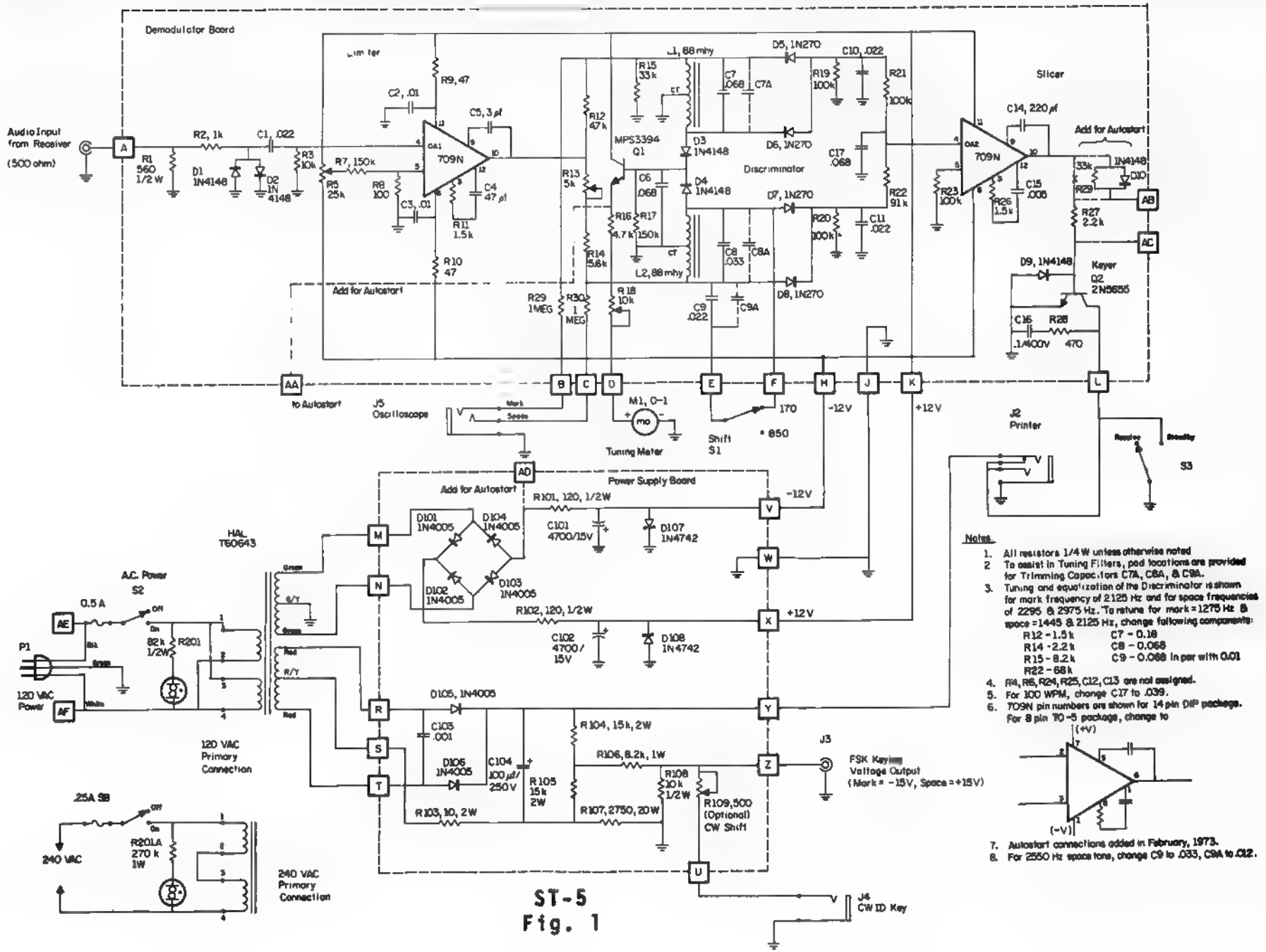
With no input signal, or with the input grounded, adjust the pot on the limiter for zero volts dc at pin 6. If this isn't possible, you'd better write me and explain thoroughly, as you probably ruined the op amp somehow. By the way, unless you get too much voltage on pins 2 or 3, like the full power-supply voltage, or get the plus-minus hooked up backwards, it's very difficult to ruin these things. By following even the most elementary construction practices, you'll have no problems with the 709C.

After balancing the limiter for zero volts output, connect the receiver and tune to maximum mark and note the indication on your tuning indicator (**fig. 4**) or on a voltmeter connected to point A. Tune to space on the receiver and again note the reading. If the indications are not the same, adjust the 5k pot on the limiter output until they are. You have now finished all the adjustments and they should require no further attention at any time unless you switch to 170 shift, for instance. In this event you may or may not want to reset the filter balance pot. I suggest you leave it for the 850 setting and take what you get on the 170-switch position, as this is a somewhat artificial method of getting good 170-shift reception.

When transmitting be certain to first close the standby switch or you can get feedback, which will produce errors similar to those you would get when using a microphone if you didn't turn off the speaker.

OTHER OP AMPS

The 709C is to other op amps what the Ford V-8 was to other automobiles. It not only led the way; it's still in use. The 709C was (and is) one of the cheapest ICs of its type available. One would


Demodulator Board
Limiter
Audio Input from Receiver (500 ohm)
R1 560 1/2 W
R2, 1k
C1, .022
D1 1N4148
D2 1N 4148
R3 10k
R7, 150k
R5 25k
R6 100
C3, .01
C2, .01
R9, 47
C5, 3 pf
709N
C4 47 pf
R11 1.5k
R10 47
Add for Autostart
R12 47k
R13 5k
R14 5.6k
R15 33k
L1, 88 mhy
MPS3394 Q1
D3 1N4148
D4 1N4148
C6 .068
R16 4.7k
R17 150k
L2, 88 mhy
C7 .068
C7A
C8 .033
C8A
Discriminator
D5, 1N270
D6, 1N270
D7, 1N270
D8, 1N270
C10, .022
R19 100k
R20 100k
C11 .022
R21 100k
R22 91k
C17 .068
Slicer
C14, 220 pf
R23 100k
C15 .006
R26 1.5k
Add for Autostart
33k
1N4148
D10
R29 2.2k
AB
AC
D9, 1N4148
Keyer
Q2 2N5655
C16 .1/400V
R28 470
R29 1MEG
R30 1 MEG
R18 10k
C9 .022
C9A
D8, 1N270
AA
to Autostart
J5 Oscilloscope
Mark
Space
M1, 0-1
Tuning Meter
Shift S1
170
850
-12V
+12V
J2 Printer
S3
Receive
Standby
AD
Add for Autostart
Power Supply Board
R101, 120, 1/2W
C101 4700/15V
D107 1N4742
D101 1N4005
D104 1N4005
D102 1N4005
D103 1N4005
R102, 120, 1/2W
C102 4700/15V
D108 1N4742
D105, 1N4005
C103 .001
D106 1N4005
C104 100 µf/ 250V
R105 15k 2W
R103, 10, 2W
R104, 15k, 2W
R106, 8.2k, 1W
R108 10k 1/2W
R109, 500 (Optional) CW Shift
R107, 2750, 20W
J3
FSK Key Voltage Output (Mark = -15V, Space = +15V)
J4 CW ID Key
HAL T60643
A.C. Power S2
0.5 A
AE
AF
P1
120 VAC Power
82k 1/2W
R201
120 VAC Primary Connection
.25A SB
240 VAC
R201A 270 k 1W
240 VAC Primary Connection
Notes
1. All resistors 1/4 W unless otherwise noted
2. To assist in Tuning Filters, pad locations are provided for Trimming Capacitors C7A, C8A, & C9A.
3. Tuning and equalization of the Discriminator is shown for mark frequency of 2125 Hz and for space frequencies of 2295 & 2975 Hz. To returns for mark = 1275 Hz & space = 1445 & 2125 Hz, change following components:
R12 - 1.5 k C7 - 0.18
R14 - 2.2 k C8 - 0.068
R15 - 8.2 k C9 - 0.068 in par with 0.01
R22 - 68 k
4. R4, R6, R24, R25, C12, C13 are not assigned.
5. For 100 WPM, change C17 to .039.
6. 709N pin numbers are shown for 14 pin DIP package. For 8 pin TO-5 package, change to
(+V)
(-V)
7. Autostart connections added in February, 1973.
8. For 2550 Hz space tone, change C9 to .033, C9A to .012.

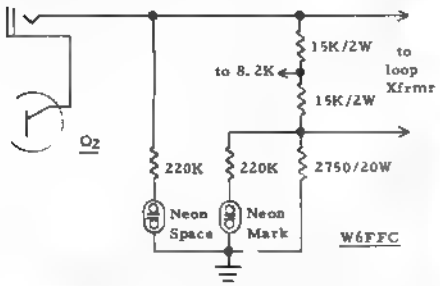
ST-5
Fig. 1

gain very little and stand to lose a lot by trying to sbustitute other units. The 741 and 748, for example, have a bit more gain, higher input voltages, and require no frequency compensation. Their biggest disadvantage here is that they're not at all suited as audio amplifiers. At 2 kHz they have only 30-40 dB gain and make a poor audio limiter compared with the 709C. So unless you know what you're doing, stick to the 709C.

*Hamilton Electro Sales, 340 East Middlefield Road, Mountain View, Calif. 94040 and G.S. Marshall Co., 732 North Pastoria Avenue, Sunnyvale, Calif. 94086 (also carries Signetics). If buying Motorola version, ask for the MC-1709CG. Texas Instruments 709 op amps are $1.50 each (or 7 for $10) from HAL Devices, Box 365H, Urbana, Illinois 61801; ask for SN72709L.

MARK-SPACE INDICATOR LAMPS

Adequate indicator lamps to show mark or space are shown in the partial drawing of the loop supply. Any type of low-current neons should be suitable. Their use does enhance tuning in a signal and they help to indicate if a station is upside down or not.



MARK & SPACE INDICATOR NEONS

NORMAL-REVERSE SWITCH

No no..nal-reverse switch has been added to the ST-5. While possible to incorporate one, (see the ST-6 schematic) it seems hardly necessary. At my station, I do not recall having heard more than 1-2 stations "upside down" in the past year. Using the other sideband on the receiver normally accomplishes the same thing as a reversing switch.

THE ST-5 AND 170 SHIFT:

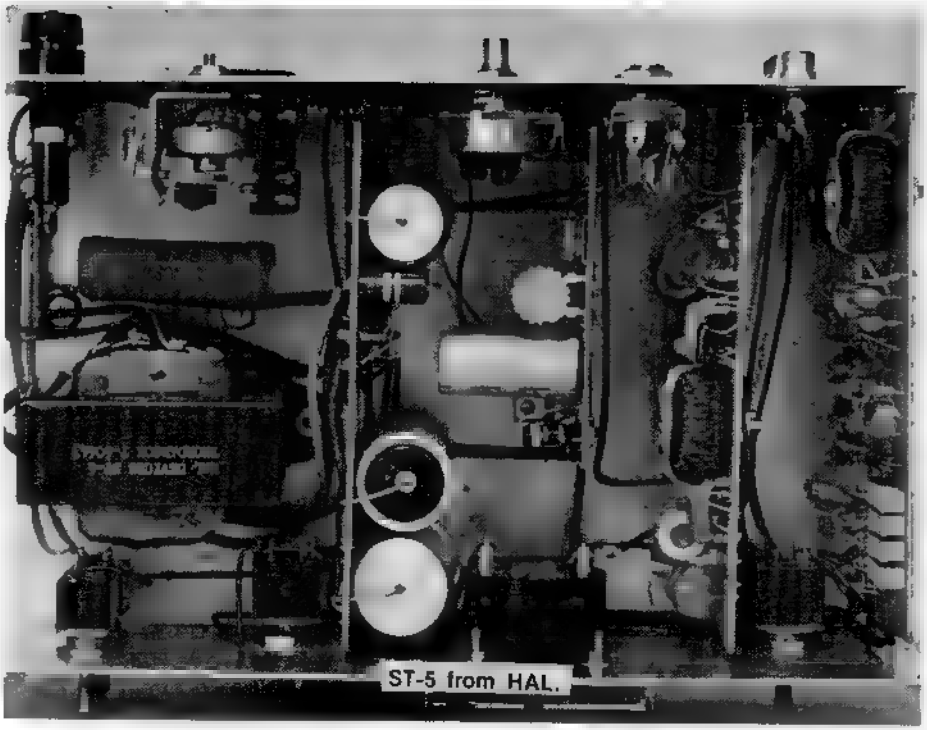
At the time the ST-5 was originally designed, a majority of stations were on 850 shift. These days, only a few stations use 850 shift on H.F.; nearly everybody having switched to 170 shift. If you wish to optimize the ST-5 for 170, you would want to use the following component values:
(ST-5 b.)

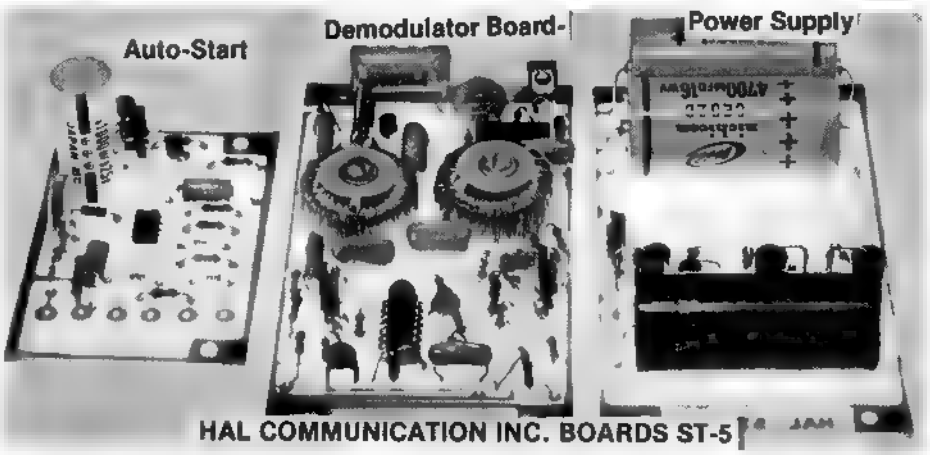
170 Shift Values	
R12	6800
R14	6800
R15	100K

THE POWER SUPPLY

Several transformers are suitable for the loop supply such as the Stancor PA-8421, or the Triad N51-X. Almost any transformer rated for 24 volts C.T. will be suitable for the power supply, if rated at least 200 mills. (The relay will take about 100-150 mills, depending upon brand.)

Hal Communications has a special transformer made exclusively for them by Stancor which combines both the loop and power windings. This saves not only space but money.



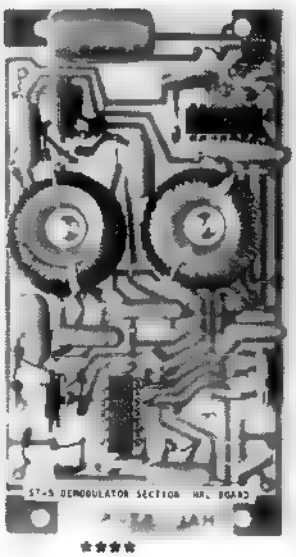


CONCLUSION

The ST-5 was designed as a simple but highly effective rtty demodulator using the best of currently available concepts. It should be a very popular unit for some years to come, as it's impossible to imagine at this time how any additional performance could be made available - it's already ridiculous to talk in terms of 90+ dB amplification. Only a completely different concept of rtty processing could outdate the ST-5, and that seems quite unlikely to occur until we all get computer terminals in the shack.

references

1. RTTY, November, 1964; also QST, August, 1965.
2. RTTY Journal, September, 1967; also QST, May, June, 1969.
3. RTTY Journal, September, 1968; also QST, April, 1970.



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Auto-Start for the ST-5 Demodulator

IRVIN M. HOFF, W6FFC
12130 Foothill Lane
LOS ALTOS HILLS, CA. 94022

The ST-5 was designed to be as simple as an adequate demodulator could be. At the time it was offered, the ST-3 provided a modest-cost unit with autostart and motor delay. The ST-3 is now considered somewhat obsolete, partially because the General Electric PA-238 op amp is no longer available. After a number of people tried to modify their ST-5 for autostart by adapting portions of the ST-3 or ST-6, we decided to see if a simple autostart could not be developed directly for the ST-5.

The results have been quite satisfactory. One op amp and two transistors plus a relay have been used.

CHANGES TO THE ST-5

The only changes to the ST-5 needed to adapt the autostart section are the addition of a 33K resistor and parallel diode on the output of the slicer op amp. This is shown in the upper-left corner of the diagram. This makes the output of the slicer circuit identical to that of the ST-6. The input of the autostart is marked "AA", and connects to the emitter of the meter transistor.

ADJUSTMENTS:

There are literally no adjustments at all. The silicon diode on the non-inverting input of the 741 holds the bias on the op amp to approximately 0.7 volts. The divider network on the inverting input allows the voltage with authentic RTTY signal (properly tuned) to rise to approximately 0.9 volts. As the voltage rises higher than 0.7, the output of the op amp switches rapidly from positive output to negative output, turning the motor on and removing the voltage on the base of the keyer stage that was holding it in standby with no signal.

PROBLEMS TO CONSIDER:

There are a number of problems in designing a suitable autostart system. First it should ignore voice or C.W. on the frequency. To do this we require it to respond only to signals which are the equivalent of at least 70-80% key down, continuously. So it will not turn off too quickly for static bursts, momentary interruptions, etc., we ask it to continue for about 1 second after the signal stops. (At 60 speed, this would print about 5-6 random garble characters.) With this in mind, the turn-on time then would need to be about 3-4 seconds, or the equivalent of about 20-22 characters. Finally, we hope it will be able to copy stations at least 40-50 Hz. off the frequency, assuming their shift is correct.

HOW IT WORKS:

With no signal, there will be a random voltage level showing on the meter. This should be significantly less in amplitude than the value shown on the meter when a signal is present and tuned in for maximum indication.

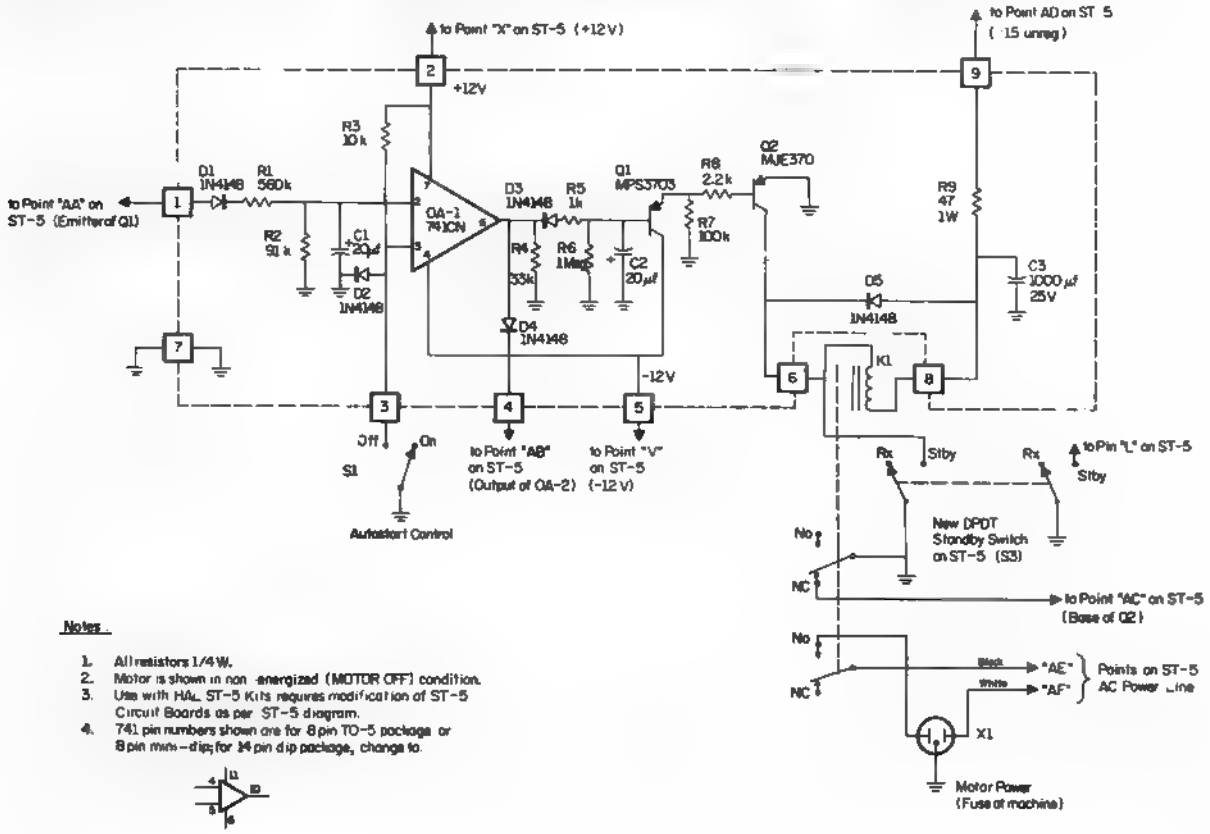
With no signal, the voltage at the emitter of the meter transistor is passed to the autostart circuit through the diode, and then via the divider network charges up the 20 Mfd. capacitor. Due to the time constants involved, this voltage will not be as great as the 0.7 volts on the non-inverting input of the 741. Thus the op amp has positive voltage on its output. This is passed through one diode to point "AB" and holds the base of the keyer transistor in markhold. At the same time, the other diode blocks this positive voltage at the output of the 741, thus the motor control circuit is not activated and the motor remains off.

When a signal appears, the voltage at the meter rises, thus the charge on the 20 Mfd. capacitor at the input to the 741 also rises. As it passes 0.7 volts, the op amp switches abruptly, and now has negative voltage on its output. The diode at AB now blocks this voltage, allowing the keyer transistor to print the incoming signal normally, and at the same time the other diode allows this negative voltage to pass, quickly charging the 20 Mfd. capacitor at the base of Q3. As Q3 conducts, it puts voltage on the base of Q4, allowing it to conduct, operating the relay and turning the printer motor on.

When the signal stops, the voltage on the 20 Mfd. motor capacitor bleeds off slowly, due to the high impedance of the emitter-follower circuit. Approximately 25-30 seconds later, the motor turns off. This delay may be shortened by lowering the value of the 1M resistor in parallel with the 20 Mfd. capacitor, or by using a smaller value of capacitor. This time was chosen to keep the motor from turning off prematurely if a person was sending compulsory c.w. identification, or was a little slow in turning on his transmitter.

TRANSISTORS:

Q2 is any high-voltage transistor



Notes:

1. All resistors 1/4 W.
2. Motor is shown in non-energized (MOTOR OFF) condition.
3. Use with HAL ST-5 Kits requires modification of ST-5 Circuit Boards as per ST-5 diagram.
4. 741 pin numbers shown are for 8 pin TO-5 package or 8 pin mini-dip; for 14 pin dip package, change to

capable of handling 300 volts or more. Several suitable choices are made by Delco, International Rectifier, Motorola, the HEP line, RCA and others. Several of those firms now make 450 volt transistors that are small and low-cost.

Q3 is a PNP, and almost any silicon type should be suitable. A Motorola MPS-3703 is one suggestion and the 2N3906 is another.

Q4 is also a PNP, but here a high-current type should be used, as it will drive the relay. A good suggestion would be the Motorola MJE-370.

THE RELAY:

The relay is a 12 volt type with DPDT contacts rated at 10 amps. You could "get by" with 5 amp ratings, but the surge current on the motor would be a bit hard on this type of relay. A suitable relay would be the Potter & Brumfield KA11DG. As this is a 12 volt relay and you will be using unregulated "12 volts" to operate it, a series resistor of 47 ohms is shown to keep the current to that recommended in the relay. This resistor is only a suggested value and might need to be changed. The higher voltage is advantageous as a "starting kick" for the relay.

A diode is placed in parallel with the relay coil to prevent back emf from the inductive spike from damaging the transistor when the relay opens.

AUTOSTART OFF SWITCH:

In the event the operator wishes to turn the autostart off, S4 is closed.

STANDBY SWITCH:

The original standby switch was a SPST across the collector and emitter of the keyer transistor. This is still adequate, but at times the motor might turn off when transmitting, if the receiver is carried in standby, prohibiting the audio signal from operating the autostart. Changing the standby switch to a DPST and using the second pole to ground the collector of the Q4 transistor will keep the motor on while transmitting -- quite often you will not be exactly on the same frequency with your receiver as you are transmitting on, and this will prevent the motor from turning off.

Another possibility would be to use the second section to parallel S4 during standby, as this would provide similar results, but keep the 20 Mfd. motor delay capacitor charged up as well.

THE MOTOR JACK:

Many printers have 3-wire plugs, so we suggest you use a polarized 3-way connector on the ST-5A. Many cases have been reported where a printer is 120 volts with respect to other items in the shack that are grounded. Using grounded connectors and 3-way wires to the printer should effectively prevent voltage differences from appearing. We would also suggest your using a 3-way cable and connector on the ST-5A, as well. Be sure the jack on the collector of Q2 for the teleprinter is insulated from ground.

TURN-ON TIMES:

If the turn-on time and turn-off times do not seem suitable, some adjustment can be made by changing the 91K resistor to the next larger or next smaller size. However, 3-4 seconds is considered normal for this type of autostart, and this is similar to the concept used on the other Mainline demodulators. If you insist on having a faster turn-on time, you could also use a smaller capacitor than the 20 Mfd. shown. That would still retain the 70-80% continuous key-down requirement to ignore c.w., etc.

CAUTION:

Be certain to use PNP type transistors for Q3 and Q4, and note they connect to negative voltage. Also be careful to orient the capacitor on the base of Q3 with its positive terminal grounded!

CONCLUSION:

Its simplicity is in keeping with the design concept of the ST-5, which was to give adequate performance from a very simple circuit. Adding the autostart converts the ST-5 to a ST-5A. Boards and components for up-dating the ST-5 or for building the ST-5A are available from Hal Communications and Autostart allows the operator to leave the room temporarily, or even to monitor a frequency 24 hours a day, unattended.

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Improved Scope Display

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INTRODUCTION:

Solid-state demodulators such as the ST-5 and ST-6 use relatively low-voltage power supplies as compared with tube type units like the TT/L, etc. As a result some oscilloscopes of modest gain give mediocre displays when used with these units. Additional tuned circuits could be used for more precise tuning and straighter lines on the scope, but these further reduce the voltage to the oscilloscope. Finally some scopes have rather low impedance inputs that tend to unbalance the discriminator output and further reduce the voltage available. The following paragraphs will describe a simple and low-cost circuit that provides ample gain, very high input impedance, very low output impedance and excellent precision for sharp and accurate tuning.

THE CIRCUIT:

The scope output of the ST-6 is run through an isolation resistor. A 3.3 meg is suggested. After this a parallel-tuned 88 Mh. toroid is connected to the non-inverting input (marked plus) to ground. The dual 741 op amp then amplifies the small voltage (approximately 70 millivolts by this time) back up to about 10 volts peak-to-peak at the output of the op amp. The tuned toroid not only gives a very sharp, precise tuning display, it also has sufficient selectivity to give virtually straight lines on the scope in place of the customary "bananas" seen with simple linear discriminators.

The input impedance at the non-inverting input (marked plus) is very high, in the order of at least several hundred megohms. The output impedance is very low, typically less than one ohm. The circuit can be used successfully with low impedance scopes such as the Heath Monitorscope, etc.

COMPONENTS:

The dual op amp may be any of a variety of integrated circuits. Individual 741 units may be used which sell for $0.50 each at places like Poly Paks. The dual 741 mini-dips sell for about $1.25. The Signetics N5558V is a dual op amp as is the Motorola MC1558G. If you have a nearby Radio Shack outlet, their item 276-028 at $1.50 is equally acceptable.

TUNING THE TOROIDS:

Use an identical technique to that used when constructing the demodulator in the first place. If a digital counter is handy the entire job becomes fairly simple. One toroid is tuned for mark tone and the other tuned for space tone.

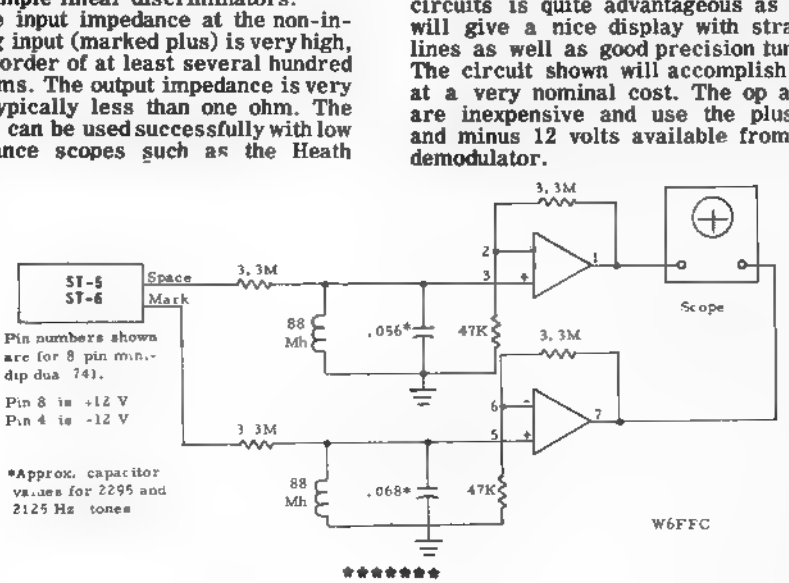
A suitable audio tone from the receiver may be used to tune the filters, but in this case use as large a resistor between the audio source and the tuned circuit as is convenient - - at least 100K.

You can also tune the toroids "in place" in the circuit shown. The op amp not only will isolate the circuit but also has enough gain to allow use of a normal VOM while tuning the toroids.

The output of this circuit is typically 10 volts AC, peak-to-peak. This should be substantially more than minimum necessary to run even the most modest scope.

SUMMARY:

The scope output voltage of solid state demodulators such as the ST-5 and ST-6 is relatively low. It may be insufficient to give a suitable display on oscilloscopes with modest gain. In any event, the use of additional tuned circuits is quite advantageous as they will give a nice display with straight lines as well as good precision tuning. The circuit shown will accomplish this at a very nominal cost. The op amps are inexpensive and use the plus 12 and minus 12 volts available from the demodulator.



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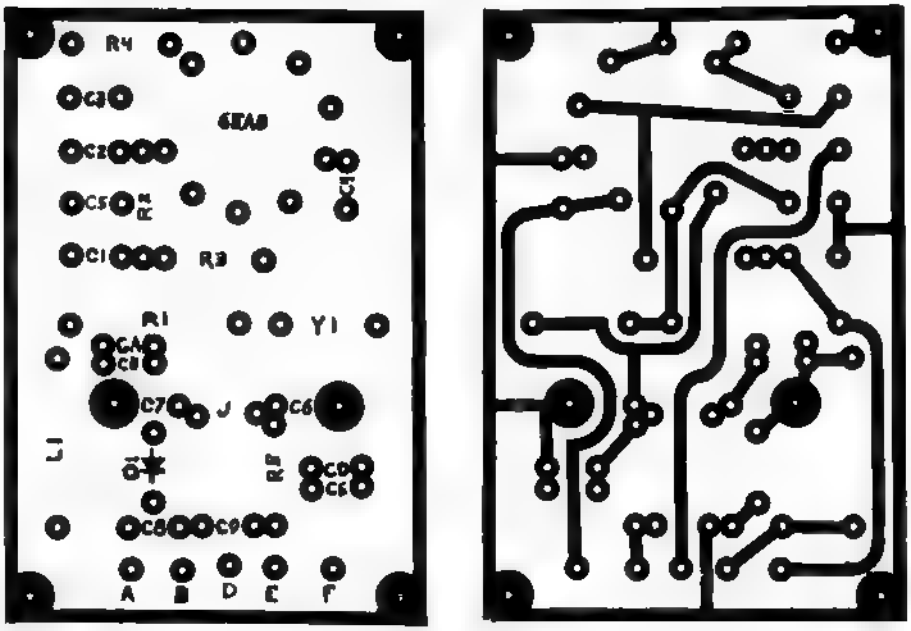
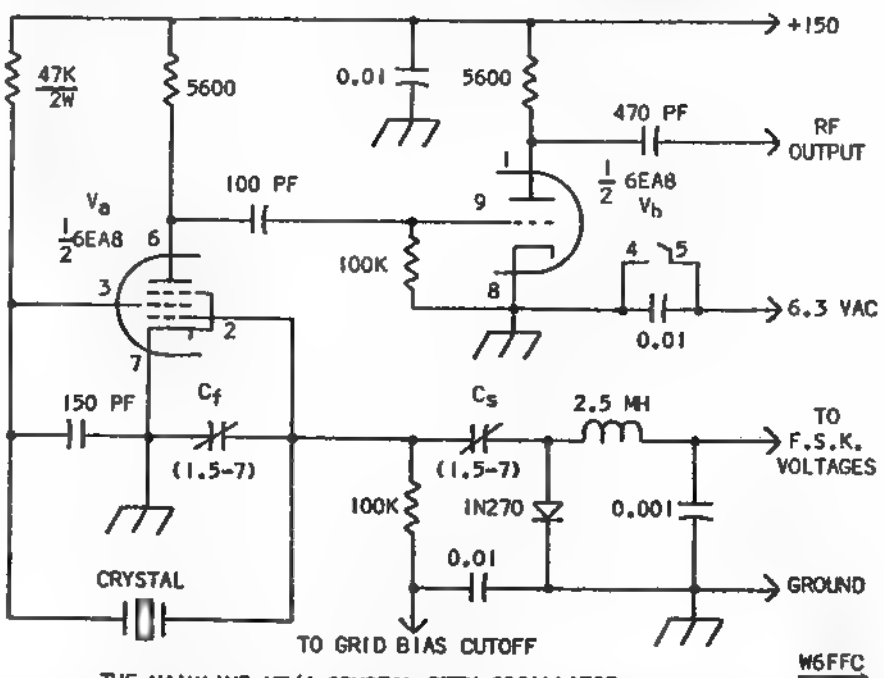
3 Band-Xtal Controlled, Receiver and Transmitter, for $100.

TRUMAN BOERKOEL, K8JUG
2888 Edwin Drive
XENIA, OH 45385



Y1-Xtal
CA, CB, CD, CE - padders
D1-1N270
A--150VDC
B-FSK voltages
D-RF output
E-Grid bias cutoff
F-6.3 VAC
J-Jumper
R1-47k 2 Wt.
R2, R3 - 5.6 K
R4, R5 - 100 K
C1, C4, C9 - .01 uf
C2-470 pf
C3-100 pf
C5-150 pf
C6, C7 - 1.5-7 pf piston
C8-001 uf
L1-2.5 mh

Parts & Placement for the WA8NGJ board.



THE MAINLINE XT/4 CRYSTAL RTTY OSCILLATOR

This is enough to raise some eyebrows, but let's be more specific. Would you believe excellent copy on 170 shift and stability so precise that unattended auto start is easily accomplished.

The above is how my article started when it was published in the RTTY Journal back in December 1967. A number of changes can now be added to this original article. W6FFC Irv Hoff's XT-4 crystal oscillator will be incorporated. And WOKXZ Jack Headley's article on the conversion from 15 to 20 meters will also be included.

The unit we are talking about is Heath Kits HW-16 Novice 3 band transceiver. The receiver contains an RF amplifier, hetrodyne mixer, crystal controlled hetrodyne oscillator, bandpass coupler, variable VFO, VFO mixer, crystal filter, if amplifier, product detector, crystal controlled BFO, and 2 audio amplifiers; sensitivity, less than 1 microvolt for 10 DB signal-pulse-noise to noise ratio; selectivity, 500 cycles at 6 DB down.

Sounds like a winner for 170 cycle shift, but there are some problems. First apparent thing is that the BFO crystal comes out on the wrong sideband and not in the center of the passband for 170 cycle shift. This must be changed.

Computations for determining crystal frequency for the receiver section, thanks to W8SDZ Keith Peterson.

Assuming that the half-lattice filter operates as they normally do, the center frequency will be half-way between two crystals, this is 3395.300 Kcs. When working with RTTY, it is easier if you convert everything to center frequencies. For instance the 3637.500 Kcs. channel is a center frequency of 3637.415 Kcs.

3637.500 Kcs. desired receiver frequency
\- .085 (.085 Kcs is just half of 170 cycles)

3637.415 Kcs. desired receiver center frequency

Heath Kit transceiver

9045.000 high frequency oscillator
-3637.415 channel center frequency

5407.585 first IF frequency
-3395.300 second IF center frequency

2012.285 second hetrodyne osc. VFO

The desired audio center frequency is
2125
85

2210 cycles
Heath kit
3395.300 second IF center frequency
\- 2.210 audio center frequency

3393.090 VFO crystal frequency

Using the center frequency approach is possible because you know that you have plus or minus 150 cycles bandwidth (at IF) on either side of it. It is therefore possible to state: For the Heath Kit HW-16 CW transceiver and the 80 meter auto start frequency, one would need a 2012.285 Kcs. crystal to replace the receiver VFO, and 3393.090 Kcs. crystal to replace the present receiver BFO crystal.

To crystal control the receiver, it is necessary to disconnect the variable receiver condenser at point "X" on the receiver printed circuit board (this eliminates L-7, C-55, C-54 and C-53 from the circuit). Using the vacated hole at point "X" on the P.C. board as one hole for mounting the crystal, drill

another hole in the P.C. board so that the crystal can be mounted from point "X" to ground. Solder this crystal in the same manner used to mount the other crystals on the P.C. board. If you desire to use crystal controlled receive on 3675.500 Kcs., use a 2012.285 Kc crystal. If the frequency needs pulling one way or the other to zero a few cycles, you may adjust the frequency by varying the tuning of L-6 on the P.C. board.

The side tone that is built into the HW-16 must be disabled. Disconnect one end of the neon lamp associated with the side tone generator to accomplish this. By removing the side tone function, the receiver will be capable of monitoring the transmitted signal.

It may be necessary to install, on the back panel, a speaker matching transformer to match the input impedance of your particular terminal unit. Put a pad on the speaker, so the speaker may be run at normal room audio levels, yet supplying the terminal unit with adequate audio to fully saturate the limiters.

Transmitter modifications: So far this has been a "No Holes" modification. However, I strongly suggest that the Sylvanin grasshopper type power supply fuse be replaced with a conventional fuse. To do this, mount a fuse holder on the back apron of the HW-16. Remember, this fixed frequency net type operation is a 24 hour unattended business and if something goes wrong the grasshopper fuse will open, and when cooled down, reset, open again, etc. until it is discovered that something is wrong. This may be too late, as it happened to me after 6 1/2 years of continuous operation where darned near everything melted.

The XT-4, Irv Hoff's crystal oscillator, which has been reprinted here, may be built into a small Bud minibox with an octal plug mounted on one end of the box to match the octal accessory socket on the HW-16 in the following manner. Plus150 volts to pin 7, 6.3 VAC to pin 2, ground to pin 1, grid bias to pin 8, FSK voltage & RF output are connected to two phono jack connectors mounted on the other end of the Bud mini-box. RF output may be connected to the HW-16 VFO input jack with a short length of coax. FSK voltages may be taken from the FSK keyer in the terminal unit with a length of coax. Terminal units such as the TT/L types, ST-3, ST-4, ST-5, ST-6 are tailor made for the XT-4.

B plus of 310 volts is already connected to pin 4 of the HW-16 accessory socket. It will be necessary to connect a 10K ohm 2 watt voltage dropping resistor from pin 4 to pin 7 of the accessory socket to supply the needed plus 150 VDC to the XT-4.

WA8NGJ, Doug Williamson, has designed a printed circuit board for the XT-4. This will simplify the construction of the unit and has allowed us to reprint his layout here, showing both the foil side and parts placement. This will enable the builder to reproduce this board easily. The board may be mounted on the top side of the bud minibox, or be mounted on the inside of the HW-16, as will be shown in a 20 meter conversion article later.

Rapid switching may be accomplished at a remote location such as a switch on the keyboard of the printer. This switch would short the key jack located on the back apron of the HW-16. When closed, it will automatically actuate the transmitter and simultaneously mute the receiver by means of the automatic switching designed into the HW-16.

A note should be made about true transceiver type operation. Most transceivers use portions of the receiver and portions of the transmitter for dual function purposes, therefore it is impossible to tell exactly what your transmitted frequency is. The HW-16 is a completely separate receiver and transmitter. If you desire, you may leave the receiver connected to the input of the terminal unit and monitor your transmitted signal on the terminal unit scope.

Those interested in the theory behind the XT-4 crystal oscillator are encouraged to read Irv Hoff's article published in the December 1967 RTTY Journal.

Following is a Crystal Chart of the more popular auto start net frequencies.

HW-16 Receiver Crystal Frequencies

	80 METERS		40 METERS		20 METERS	
Operating freq.	3637.500	3617.500	7137.500	7117.500	14,082.500	14,075.000
Receiver osc. xtal	2012.285	2032.285	2012 285	2032.285	2 067.285	2 074.285
HFO xtal	original	original	original	original	19,545.000	19,545.000
BFO xtal	3393.090	3393.090	3393.090	3393.090	3 393.090	3 393.090
XT-4 xtal	3637.415	3617.415	7137.415	7117.417	7 041.200	7037.000

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Converting the HW-16 to 20 Meters

Converting the receiver and transmitter to 20 meters
Mechanical stability
Receiver AVC
Internal mounting of the XT-4
Front panel receiver vernier tuning

Converting the receiver section of the HW-16 from 15 to 20 meters. Remove the 26,545.000 kHz 15 meter HF oscillator crystal. Replace it with a 19,545.000 kHz crystal. Install a 10 pf mica capacitor across L4. With the aid of a grid dip meter, tune L4 to 19,545.000 kHz. Remove L1, unwrap the old windings and rewind the coil form with 12 turns of number 22 enamel wire. reinstall L1. With the aid of a grid dip meter, tune the coil to 14 MHz. Install the appropriate desired receive frequency crystal from point "X" on the receiver P.C. board, to ground. Refer to Part I in the July 1974 RTTY Journal for the procedure required to calculate this crystal frequency, also refer to the "Popular Net Frequencies" chart to be sure that you are in the right ball park.

Converting the transmitter section of the HW-16 from 15 to 20 meters. Install a 20 pf mica capacitor across L9. With the aid of a grid dip meter, tap on L16 (final tank coil) 3 turns up. The transmitter doubles to 14 MHz and 7 MHz crystals are used in the XT-4 for operation on that band.

You may desire to stop at this point; however, some instability is inherent on 20 meters. This condition is both mechanical and electrical.

Most of the mechanical instability is the result of the light hook-up wires connected to the band switch. I would suggest that this wiring be replaced with a heavier bus bar.

Electrical instability is primarily due to the unregulated voltages at the receiver oscillator stages. Install a VR150 voltage regulator tube and socket in the front outer corner of the HW-16 receiver section. The center of the VR150 tube socket should be 1" from the right hand edge of the chassis and as close to the HW-16 receiver P.C. board as possible. This will allow adequate room to install the XT-4 piston trimmers on the front panel. Solder a one lug terminal strip on the circuit board foil on the ground bus near point "P". Connect a wire from this lug on the terminal strip to pin 5 of the VR150. Remove R31 from L6 to point "P" on the circuit board. Connect a 5600 ohms 1/2 watt resistor from L6 to the terminal strip. Connect a 4500 ohm 10 watt resistor from the terminal strip to point "P" on the circuit board.

Receiver AVC may be added by using a CK1121 Raytheon Raysistor. The socket which is supplied with the CK1121 may be mounted in any convenient place on the back apron of the HW-16. Hold the socket with the pins up and the two close-spaced pins away from you. Number these two close-spaced pins, 2 & 3, the left hand lower pin number 1 and the lower right hand pin number 4. Pins 2 & 3 are grounded. Pin 1 is connected to pin 2 of V6A on the HW-16 receiver P.C. board. Connect pin 4 of the Raysistor to pin 1 of the phone jack from the audio output of transformer T4. Remove R70 (10 ohms) from the audio output transformer T4.

Internal mounting of the XT-4. As described in the July 1974 RTTY Journal, the XT-4 may be built either on a small P.C. board, or hand wired. In either case, the most convenient spot to mount the XT-4 is at the present location of the receiver VFO capacitor (C53).

If you are using the P.C. board, remove the receiver VFO tuning capacitor and either move or remove the adjacent dial light and associated parts. Using 1/2" metal spacers, mount the P.C. board to the metal chassis above the vacated area of the VFO capacitor. Remove the two JFD glass piston trimmers from the P.C. board and, using insulated hardware for the one trimmer that is above ground, mount the two trimmers on the front panel of the HW-16. This will permit easy access for the fine adjustment of both mark and space frequencies of the XT-4.

Using the hand-wired mounting for the XT-4, remove the receiver VFO capacitor. Mount a tube socket for the 6EA8 tube and associated terminal strips needed. Mount the JFD trimmer capacitors on the front panel of the HW-16 in the same manner as used in the P.C. board mounting. The only difference is that the trimmers will be mounted below the main chassis of the HW-16.

Obtain your plus-150 volts from the now regulated plus-150 volts from the VR150 voltage source. The RF output is connected to pin 2 of V7 on the HW-16 receiver P.C. board. Mount an RCA phone jack on the back apron of the HW-16 to bring in the FSK keyer voltages to the XT-4. Grid bias cut off voltage for the XT-4 may be picked up at point "Y" on the HW-16 receiver P.C. board. 6.3 VAC may be picked up on pin 3 of V4 on the HW-16 receiver P.C. board.

Now that you can tune the XT-4 from the front panel of the HW-16, mount another 1.5-7 pf JFD piston trimmer next to the two already mounted on the front panel of the HW-16. Connect this trimmer to point "X" on the HW-16 receiver P.C. board. You now have a small vernier padder across the VFO replacement crystal, which will allow you to zero the crystal to the desired frequency and will also allow you to peak the coils of the receiver in accordance with the Heath Kit manual.

Bibliography
HW-16 Conversion
Boerkoel
RTTY Journal Dec. 1967
XT-4 Crystal oscillator
Hoff
RTTY Journal Dec. 1967
HW-16 20 meter conversion
Headley
RTTY Journal June 1968

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RTTY OPERATING PROCEDURES

GETTING STARTED

Operating procedures and customs differ on RTTY as with other modes. Legal identification by readable CW is required by law. Other customs and habits are determined by the operator and to some extent by the equipment in use. As a suggestion to beginners the following procedures are listed.

CW IDENTIFICATION

Your call (only) must be sent on READABLE CW at the beginning and end of each transmission. As on other modes stations breaking back and forth may omit this identification as long as it is given at least every ten minutes. No station identification is required from the printer but it is usual to give it at the end of each transmission as a courtesy to other stations listening. It is not necessary (or good practice) to print "CW Id to follow" at the end of any transmission.

CALLING A STATION

Zero his frequency-CW ID - then call similar to other modes. Be sure to repeat your call several times as this gives the other station a better chance to get your call correct. After a QSO is established a single call is enough or just a BK.

CALLING CQ

Please keep them brief. A whole line of CQs across the paper is an invitation for a station to look elsewhere. Send 3 or 4 CQs and then your call at least 3 times and repeat for several lines and then LISTEN. If no answer repeat for several times. Any experienced RTTY operator can recognize a CQ by ear but not your call so be sure to include it a number of times. Many like to include their name just before signing. AND be sure you listen to the frequency for other stations before starting.

BREAKING IN A QSO

Wait until the CW ID of the transmitting station is finished - give your CW ID and then BK de (your call). It is not necessary to give any or all of the calls of the other station now. If acknowledged make a short transmission or ask a question if you have one and then turn it to the next station in the group.

TYPING

Unfortunately many of us are not good typists and a beginner is also very apt to be nervous. Do the best you can, most RTTY operators can remember their first attempts and are very tolerant. If you are a slow typist help speed things up by economizing on words, no need to apologize or explain that you are slow - he knows it by now anyway. Give him your name - location or anything else of interest. Abbreviate words when possible such as CW operators use. Practice when you have a chance and you will soon pick up speed. If you have a TD (Tape transmitter) make some tape while the others are printing and when your turn comes you are all ready for a fast answer.

TECHNICAL TYPING HINTS

Today there are many different types of printers in use, many with various automatic devices for giving automatic carriage returns, line feeds etc. However, you can not go wrong with the following sequence at the end of each line (72 characters or less). TWO CRs, one LF and one Ltrs. The 2 CRs make sure that one is received and starts the carriage returning, the LF turns up another line and the LTRS gives a little time for all of this to happen as well as making sure the machine is in lower case. This will work with about all machines including those with automatic features. Most machines are fixed to return to lower case on a space, if sending numbers or upper case remember this and hit the FIG key after each space or use the dash instead of a space. Stations using a video printer prefer none of these functions as it is done automatically and with a shorter line much space is lost with CRs inserted. If you are in a group however with regular printers as well as video use the regular procedure to prevent confusion on the regular printers.

COMMENTS

RTTY has a fine bunch of operators. If you are a beginner and are puzzled by something - ask - if possible I am sure you will get help. Most terminology on RTTY is similar to other modes. "73" means best wishes or regards. 73-73-73 means "best wishes - best wishes - best wishes." Choose the one you like best. Likewise "HI" is used to denote humor of some kind in the print just sent or received. We have never been sure but suppose that "HI-HI-HI" means a big guffaw and frankly we have seldom been affected that way over the air. One "HI" should be plenty and unless you are a Bob Hope, not too many of those. Be natural and print the same way you would talk to a person.

CONCLUSION

In spite of this long column on "do's and dont's" RTTY is a lot of fun. Usually it is easier and more fun if done the accepted way but every person is entitled to his "own thing" and this applies to RTTY also. HAVE FUN and good printing.

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PICTURES ON RTTY - How to make your own.

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One phase of RTTY that is of interest to a large group is the transmission and reception of RTTY pictures, QSL cards and even poems or quotations are popular items. Tapes of most of the popular items are available from several sources. Best of all you can make up your own art work and then exchange it with others. Don Royer, WA6PIR is probably the outstanding creator of this work and his article on how you can do your own is included here. The illustration is just a sample of a few of the pictures all made by amateurs.

****

DON ROYER, WA6PIR
16387 Mandalay
ENCINO, CA. 91436

A few years ago you were asked if you had ever wished you could create RTTY art. It is still a great deal easier than you might think.

There is much basic art work available from which RTTY pictures may be made. Comic strips, magazines, newspapers, gatefolds, photographs and copies of works of art may all serve as bases for pictures. While these may not be the right size, an inexpensive child's pantograph or some types of Xerox machines may be used to enlarge or reduce them. A portrait of Washington was made from the etching on the dollar bill. Also, if you have a little sketching talent, that will help (or enlist the help of your wife and friends). Be sure to keep your left and right margin distances in mind when sizing your art and in selecting portions of large basic material. Remember that the width limits of most teleprinters will permit a picture of only a little over seven inches wide.

After selecting your subject and sizing the art work, run about four feet of paper from your printer. Use the center portion and carefully tape or glue the drawing or photo to the paper. Trim the edges to the same width as your paper. Now remove the paper stock from your printer and insert the four-foot sheet whereby the sketch is presented to you as it rolls over the platen. Carefully align the edges of the paper on the platen. Use your line feed to bring the top of the sketch into view. You are now ready to

type the first run of your proposed picture directly upon the sketch, punching a tape as you go.

A small selection of characters is all that is needed to produce either outlined or shaded pictures. Study the letters and other characters to learn their individual densitites. For example, the M and W are the darkest, followed by the H or X and then by the I. Thereafter, you can use the upshifted characters such as the: or ; followed by the " or - or. and the like, depending upon where you want the print to fall. In this way, you may add the shading that you desire or leave certain areas blank like this:

MMHMHHHHI:I:::.'

.'.:.::I:IIHIHHMHMM

going from dark to light and back to dark again. Due to their shape, you may also desire to use the V, A, F or L at the beginning and ends of dark areas to obtain smooth lines and perhaps accompanied by an apostrophe or period. With a little practice, you will be able to tell just where any character will strike the paper. Do leave blank or white areas whenever possible and don't try to fill the entire line with characters since this is a black and white (hopefully you have white paper) picture and you must rely upon the contrast to produce the desired detail. Continue the typing process over the entire sketch.

Now remove the sketch from your printer and reinsert your paper stock. Play out the tape you have made. You will probably be pleasantly surprised. Use a red pen to indicate on the print where additions, corrections and any changes are to be made. Rerun the tape (having folded the marked-up print and following it line-by-line using the paper holder and line guide on the printer) to make corrections, punching a new tape at the same time. In most instances, a good picture may be made with a series of five or six correction tapes.

When typing on the sketch, it helps to have a strong light directed onto the sketch in your machine. This is particularly true if the contrast of the sketch is poor, as may be in color photos. Also, since you will be unable to see the part of the sketch below the ribbon, a pencil may be used to outline the areas where the shading will change from one density to another. You may thus be able to produce a more complete picture the first time thru. Some of the RTTY artists have found that it helps to make Xerox prints of the original sketches or photos and to use those for their art work, as this eliminates some shading and provides a black and white format from which to work.

Keep the detail of the original art work as large as you can and don't be afraid to experiment with different letters and techniques. Do clean up your tapes. This may be done during the first run-thru after the typing to remove any extra characters that crept in by mistake. To give you some idea of the time required to complete the pics, about 20 hours is needed for one of the playmates that runs 30 minutes or so. Most of this will be in making the corrections and in rerunning the tape. Even after they are apparently finished, hang your creation across the room to see how it looks from a distance and then make a final tape with the finishing touches, increasing or decreasing contrast in certain areas and cleaning up edge lines. Time and patience!!!

As many modern machines have non-overline features, it is generally well to

avoid overline printing. Good, non-overlined pics may be made by using the various character densities to create desired contrast. Stay within a 72 character line. Start and end the tape with a series of LTRS or blanks, a single carriage return and about ten line feeds. Keep in mind those machines which downshift on space as well as those which do not. If you are upshifted, and then space and wish another upshifted character, put in another FIGS character. Of course, the same applies when you want a letter following a space after an upshifted character and another LTRS must be added. At the start of each line, use one carriage return, the line feed and one LTRS unless the first character of that line is upshifted and requires a FIGS.

Again, make your tapes as short as possible by taking out any unneeded characters, extra LTRS, FIGS followed by LTRS and things like extra spaces or LTRS at the end of a line. Above all, be sure to put your credit line at the end, with the hope that others will follow your lead and keep it there.

There is one further situation you may wish to consider. An increasing number of machines do not use the standard communications keyboard. On these machines, the apostrophe and the bell are switched from the more normal arrangement of the apostrophe over the "J" and the bell over the "S". To enable the pictures to be printed on either machine, it is only necessary to use both of these characters. That is, every time you use an apostrophe follow it immediately with a bell. This, of course, will produce a lot of bell ringing during reception but will enable full and accurate print on either type of keyboard arrangement. Most of the commercially available picture tapes are formatted in the suggested manner.

If you make or obtain pictures that are in several panels, it is very important that your paper is very tight on your platen. Otherwise, the panels will not line up. In putting these panels together, trim the border from the left edge of the second panel and carefully align it with the appropriate edge of the first panel. You may have to compensate if the print is off a bit. The panels may be secured together with plastic tape or, better yet, with a small amount of white glue. For wall display purposes, if your paper is thin, the overlapped areas may be hidden by backing the finished print with blank paper.

So if RTTY pictures excite your imagination, how about trying your hand at making at least one? You may find some hidden talent.

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RTTY TAPE - Art and Music

In spite of the fact that more and more RTTY tape gear is being used on the air nowadays, it use seems to be limited to the customary "CQ" tape, a simple "brag" tape, and the taping of answers in a fast QSO. Perhaps the disappearance of QSL cards and similar tape art is because so little, if any, has been written about the procedures for preparing tapes. In the hope of encouraging you to "do it yourself", this article was written. Equipment needed is a printer, a typing reperforator, and a tape distributor -- or their equivalent.

The foremost RTTY artist (who made up those wonderful portraits of the Presidents) prefers to make up his preliminary sketches on graph paper. Since few households have a ready supply of graph paper, a much similar approach is to print up a page, or the desired part of a page, with the letter "O". You can do this by hand if you need the exercise, but it is better to make an endless tape

loop to automatically print the "O"s . . . start the tape with 3 letters shifts, a carriage return, a line feed, 70 "O"s, and 3 letter shifts. Splice the tape by gluing the 3 letter shifts perforations at the end of the tape of the 3 at the beginning. What glue to use on the oiled tape? An expert in office tape machines told me that "Elmer's White Glue" (R) is the best possible material for the purpose -- so much so that his company did not market its own glue for tape splicing. Use a very small amount of glue and carefully match the tape perforations. The tapered point of an ice pick is a help here. Check for straightness by setting the tape loop on edge on the table top -- if it lies flat all the way around, it is straight. You have a minute to make a slight adjustment while the glue is setting.

As an example, let's start out to make a tape for the QSL shown in Figure 1. Put the "O" tape in the tape distributor and use it to print a block of "O"s a little larger than the desired form. A nicety is to use a well-worn ribbon on the printer so that the "O"s will be just visible. Now roll the paper out of the printer and tear it off, leaving a generous top and bottom border. Take a soft lead pencil and sketch the desired design, using the "O"s as a spacing guide, as shown in Figure 2. Now put your sketch back into the printer; carefully realign it so that the typing you are about to do will exactly coincide with the "O"s previously printed by tape. Replace the worn ribbon on the printer with a good, black one. Start up the printer and reperforator, and type in the desired pattern and lettering, using your pencil sketch as a guide. To check your accuracy, run the tape through the tape distributor and print the results. Usually you will find two or three errors at this point; mark them so you can readily see them, and make a new corrected tape.

In making new tapes from old ones, I find it very handy to have a switch located alongside the printer keyboard -- this switch is connected across the signal output of the tape distributor. When you come to a point on the tape where deletions are necessary, just throw the switch to the shorting position, type in the correction, advance the tape to the point where you wish to copy it again, stop the tape, flip the shorting switch off, and you are ready to resume copying. You will be disappointed to learn that the switch cannot be used "on the fly" -- this results in misprints, ruining the new tape.

One part of the QSL shown in Figure 1 requires special treatment; the part calling for the filling in of data -- the other fellow's call, RST, time, date, etc. The QSL tape is punched so that it types the entire line, including the right border, followed by a carriage return without a line feed, followed by the number of spaces needed to put the carriage at the point where the call is to be typed in manually. At this point, the tape should have a bell signal followed by 8 to 12 letter shifts, ending with a carriage return and a line feed. The same technique is used on each of the other lines where data is to be typed in manually. In transmission, then, the procedure is to listen for the bell. When it sounds, quickly turn off the tape advance, manually type the entire line of data, and then without using the carriage return or line feed, turn on the tape advance and

FIGURE 1.

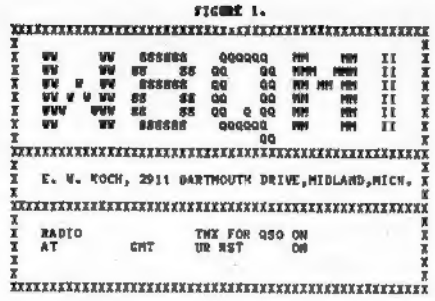

FIGURE 3.

```
                                R
                                Y
RIG HERE IS MARAUDER            R
WITH WARRIOR LINEAR             Y
TO HY-TOWER VERTICAL.           R
75-A-4 RECEIVER .               Y
RTTY -- 15  PRINTER             R
14 TD, TYPING REPERF,           Y
PRINTER, FAXD UNIT              R
W8JAV-W5ANW T R                 Y

                                7
                                3
```

wait for the next bell to signal. For the line where you are to type in the time of QSO, you may prefer to use figure shifts instead of letter shifts -- it saves you punching the figure shift key manually -- but if you do, be sure to include a letters shift at the end of the series.

This may be a good time to mention the matter of excess carriage returns. I started out in RTTY with a model 26 that never could quite get back to the left margin in time to properly print a tape-transmitted signal, so I got the habit of always inserting a few extra carriage returns on my tapes to make sure the printer had time enough to print properly. Now I learn that some of the fabulous 28s have an arrangement to line feed each time they receive a carriage return -- and a friend of mine sent me a page of copy to show how I was wasting his paper, hi! So watch those carriage returns for the sake of your lucky friends.

Now that we have struggled through the first QSL, it won't be necessary to start from the very beginning on the one shown in Figure 3. The trick here is to take a copy of the QSL of Figure 1, put it back in the printer, and then carefully type a line of "O"s to cover the open spaces only, followed by a carriage return with no line feed and an over-printing of "X"s. Note that this new QSL has an added feature -- a place for name and address, as on a postcard. When you run out of your printed QSLs you can easily run off a RTTY QSL card. The data can be filled in on the printer or with pen or pencil. Crease the copy at the bottom of the design and paste it to a 4" x 6" file card. After the paste hardens, trim the card to size, and it is ready for mailing.

For the RTTY contest man, the following should prove helpful. The first of two tapes is used in the situation where you have been calling "CQ Contest" and a station answers you. You manually type his call several times and then use the following tape:
(no carriage return or line feed) deW8QMI THANKS OM FOR THE CALL PLSS QSL MY NR UR RST DATE-TIME BAND SECTION carriage return, line feed, signal bell, and 8 to 12 figure shifts, and a letters shift) (end of tape). When the bell sounds, stop the tape advance, manually type in the data below each heading, using dashes or periods between numbers to avoid shifting.

The second contest tape is used in the situation where the other fellow has called "CQ contest" and you are answering him. When he returns, giving his text, use the second tape (similar to the first one, except for the headings which are as follows:
QSL UR NR UR RST DATE-TIME BAND
PSE QSL MY NR
FROM MICHIGAN SECTION BK BK

In use, the contest tapes should be clearly marked with a heavy lead pencil to avoid mixups in operation. They can be endless, but I prefer to have them repeated several times on a strip. If you are a slow typist, you can include considerably more routine material -- "thanks for the contact, hope you have good luck in the contest, name here is Ed, etc., etc., and for any other contest call." Use of these tapes makes for extremely rapid operation and assures you of transmitting all necessary contest data on your first transmission. If things are rough, you may want to make a reperf of your transmission so you can repeat it completely by using the reperfed tape.

Music on RTTY? Percussion is probably a better term for it. I am sure you have all heard that old refrain "Shave and a haircut" banged out on the bell signal, but I wonder if you have ever tried to do it on tape? Try this ("F" indicates a figure shift, "S" is the letter "S"):

FSFFFSSSFSFFFSFFS

If you are musically inclined, the basis for this is as follows:

one half note
    bell and seven shifts
one quarter note
    bell and three shifts
one eight note
    bell and one shift
one sixteenth note bell

Figure 4 shows the application of this to "Jingle Bells", which you may want to try for yourself. A far more interesting and "hep" version gives it a catchy New Orleans jazz beat and combines with it the typing of "Merry Christmas and a Happy New Year to All". Its reproduction is tedious but worthwhile. The hardest part is keeping track of what you have typed and what comes next. In addition to "F" and "S" as above, now "X" indicates a letters shift, and "Z" a space. Spaces shown here between symbol groups are aids in reading only -- do not

include them in your tape:
Carriage return and line feed

FSFSFSXMFS FSFSXEFSFS
FSFFSSXRRY ZFFSFSFSFF
SSFSFSFSSS
FSFSFSFSXC FSXHFSFSFS
XRFSFSFSXI FSFSFSFFSS
XSTMASFSFS
FSFFSSFSFS FSSSFSFSFS
FSXZANFSSS FSFSFSFSXD
ZAFSSSFSFS
FSFSXZHAFS SSFSFSFSFS
FSFSFSSSFS FSFSFSXPFS
XPFSFSFSXY
FSFSFSFZFS FSFSFFSSXN
EWZYFSFSFS FFSSFSFSFS
SSFSFSFSFS
XEFSXAFSFS FSXRFSFSFS
XZFSFSFSFF SSXTOZALFS
FSFSFFSSFS
FSFSSFSFS FSFSFXL
Carriage return and line feed.

FIGURE 4 JINGLE BELLS

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AWARDS FOR RTTY OPERATIONS

There have been many Awards made available to the RTTY amateur over the years and what we have tried to do here is gather them all together in one place for handy reference. The collection may not be complete but are all those we are aware of at this time. As others become known or made available to the RTTY'er we will add to the list at some future date.

We would also like to make you aware of the many fine Awards made available by the sponsors of the RTTY Contests that take place every year. They range from beautifully engraved Plaques, to gold, silver and bronze medals, down to really fine certificates for call area winners. Give it a try, you may be surprised how easily you may win one of them.

100 - DXCC - RTTY
"100 DX Countries Confirmed on RTTY"

The RTTY Journal will present the 100 - DXCC - RTTY Award to any amateur that produces proof of two-way radioteletype contact with 100 different countries. The ARRL Country List will be the final authority as to what constitutes a country for amateur radio purposes and we would advise that those interested obtain a copy of "Operating Aid Nr. 7", which is available from the ARRL.

There is no charge for the Award and it is in the form of an attractive engraved Plaque that any amateur would be proud to display. Once the Award is obtained additional "endorsements", to be attached to the Plaque will be awarded for additional countries confirmed, in multiples of Ten (10).

Application for the Award is to be made in the following way:

1. Submission of 100 or more QSL cards along with a list of the countries claimed. These are to be sent to - DX - Editor, RTTY Journal, P.O. Box 73, Blue Bell, Pa. 19422. Registered mail should be used and sufficient return postage in the form of U.S. funds or IRC should be included to have the cards returned in a like manner.
2. Less than 100 QSL cards with the balance of confirmations to be as follows. The Journal will accept written transcripts from any valid RTTY Contest Log when properly authenticated by the Contest Committee of the Society or Group running the contest, provided of course that both parties concerned submitted logs for the Contest concerned. Only contests held after January 1, 1972 will apply and it would be advisable to make such requests as soon as possible after the particular contest results are published, as we doubt that such records are held for more than a year.

QUARTER CENTURY AWARD

The Quarter Century Award (QCA) is issued by the British Amateur Radio Teleprinter Group on the submission of satisfactory proof of Two-Way RTTY communication with 25 different countries.

Measuring 10" by 13" and printed in Red and Green the Certificate makes an attractive addition to any Amateur Radio Station. Endorsement stickers are available for each additional 25 countries.

Application for the Award may be made by the following methods:

1. Submission of QSL Cards for the countries being claimed. These cards are returned to the owner after checking. Alternatively, submission of Photostat copies or clear photographs of the cards. Such copies should clearly show the call sign of the Amateur making the claim and also establish the fact that the contact was made using RTTY as the mode of communication. This type of claim must be witnessed and signed as accurate by TWO other licensed Amateurs.
2. Claims may also be accepted based on a Contest Log submitted for any Contest sponsored by the British Amateur Radio Teleprinter Group. The claim for the QCA Certificate should be made at the same time as the contest log is submitted. The cost of the certificate is 2 Dollars U.S. or 8 IRC.

Send your claims to:
Ted Double G8CDW
BARTG Contest & Awards Manager
39 Linden Gardens
Endfield, Middlesex, England.

ADDITIONAL NOTE: Holders of existing QCA Awards will automatically have any new additional countries added to their records when they submit Logs for any BARTG RTTY Contest.

W A S AWARD

WAS means "Worked All States". An Amateur, anywhere in the world, who succeeds in getting confirmed contacts with all fifty U.S. states and sends them in for examination, may receive this Award from The American Radio Relay League, 225 Main Street, Newington, Conn. 06111. There is a nominal service charge to those amateurs located within the League's operating territory (U.S., possessions, Puerto Rico, and Canada) who are not ARRL members. For others there is NO charge, except postage which is expected to accompany the cards.

You may make the contacts over any period of time and on any or all amateur bands. You may have your WAS Award issued for some special way in which you made it, in this case, ALL RTTY, - only provided that all cards submitted plainly show that the contacts took place "2 x RTTY".

Before you send your cards, drop the ARRL a line requesting a copy of the rules and an application blank.

ALL STATE RTTY AWARD

The Florida RTTY Society issues an "ALL STATES AWARD" which is awarded to any RTTY operator for two way RTTY contact with all 50 States.

QSL cards confirming contacts must be sent to the Secretary by registered mail and sufficient postage must be included to return the cards by the same class of mail. There is no other fee involved. The ASA certificate is one you will be proud to own, and if you can qualify you are urged to submit to the Florida RTTY Society, Inc., 3039 Mango Tree Drive, Edgewater, Florida 32032.

WORLD RTTY CHAMPIONSHIP

This Award which is sponsored by the Italian Magazine "CQ Electronica" is organized in order to promote greater interest for the RTTY'er taking part in the various Contests during the period of one year.

At the present time the Contests which provide scoring points towards this Award are as follows:

BARTG SPRING CONTEST
DARC WAE CONTEST
SARTG RTTY CONTEST
CARTG WORLD-WIDE RTTY SWEEPSTAKES
A. VOLTA RTTY DX CONTEST
GIANT FLASH RTTY CONTEST

The task of administering the CHAMPIONSHIP is shared between several of the RTTY Groups.

In order to arrive at the final score and to decide the winner, the following point system is used for each Contest: 30 points to the winner, 25 points for 2nd place, 22 points for 3rd place, 20 points for 4th place, 18 points for 5th place, 17 points for 6th place, 16 points for 7th place, and with one point less for each place to 22 for which 1 point is awarded and all other entrants will also be credited with one point.

For the final score each year, only the best 4 scores (out of a possible 6) of each operator will be used.

In order to take part in this Award it is not necessary for entrants to send in a claim as the entries of all competitors in all six Contests will be automatically included.

W A C - R T T Y

This Certificate was originally conceived by the RTTY Society of Southern California and issued by the RTTY Magazine, predecessor to the RTTY Journal. It is presently issued by the DX Editor of the RTTY Journal and all requests should be sent to - P.O. Box 73, Blue Bell, Pa. 19422.

In Physical appearance it is very similar to the regular/WAC Certificate as issued by the IARU, both as to size and format. The requirements are that you submit proof of two-way RTTY contact with the six Continents - North America, South America, Europe, Africa, Oceania, and Asia. There is no charge for the certificate and it is forwarded via 1st Class mail. Postage to cover mailing and return of your cards is very much appreciated.

To make it somewhat easier for Amateurs in remote areas to receive the Award and to minimize loss of cards in the mails we have at the present time a working arrangement with the Contest and Awards Managers of BARTG and SARTG for verification of WAC-RTTY. If you enter one of the annual Contests sponsored by the above Groups you may, at the same time you submit your log for the Contest, put in a claim for WAC if this had been accomplished in the course of the Contest. If the other stations submitted logs and claims is verified by the Contest Committee I will be notified in writing and the Certificate will be issued. This service is not retroactive and must be done at the time the Contest log is submitted.

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SOURCES FOR SUPPLIES

The following, listed alphabetically, are sources for many of the items mentioned in this handbook. As prices and availability change, no specific items or prices are listed. A SASE envelope to the firm will usually bring a current list and prices.

ATLANTIC SURPLUS SALES, 3730 Nautilus, Brooklyn, N.Y. 11224. Printers, TDs, parts and other TTY equipment.

ELECTRONIC DEVELOPMENTS, PO Box 951, Salem, OR. 97308. PC boards, AK2 AFSK generator, Custom cabinets, etc.

HAL COMMUNICATIONS, Inc. Box 365RJ, Urbana, IL. 61801, PC boards, ST-5 kits, Video print outs and keyboards. Kits for many demodulator and AFSK units. Finished units.

HALE ELECTRONICS, PO Box 682, Cape Girardeu, MO. 63701. PC boards and kits for character generators, etc.

C.B. GOODMAN CO., 5454 South Shore Dr., Chicago, IL. 60615. Teletype and Electronic equipment.

JIM COOPER, PO Box 73T, Paramus, N.J. 07652. Teleprinter supplies, paper, ribbons, etc. Also many manuals.

BERT KELLEY, 2307 S. Clark St., Tampa, FL. 33609. PC boards and kits for counters, freq. standards, CW ID boards, etc.

LELAND ASSOCIATES, 18704 Glastonbury Rd., Detroit, MI. Video Print Out equipment.

KEN SIMPSON, 3700 Mountainview, Alliance, OH. 44601, Demodulator kits and boards. Built up demodulators.

NAT STINNETTE ELECTRONICS, Box 1043, Tavares, FL. 32778. Boards and kits for the NS-1 PLL Demodulator.

TYPETRONICS, Box 8873, Ft. Lauderdale, FL. 33310. Printers and parts, manuals, Gears, Toroids Keytops, etc.

BACK ISSUES RTTY JOURNAL. Since very few back issues are available and references are made to certain issues throughout this handbook we are listing two sources for reproduced copies.

ATLANTIC SURPLUS SALES, 3730 Nautilus Ave., Brooklyn, N.Y. 11224.

R. WILSON, WB0ESF, 4011 Clearview Dr., Cedar Fall, IA. 50613.

Many items are advertised in the RTTY JOURNAL Classified ads each month including many private offerings of all types of equipment — for sale or trade.